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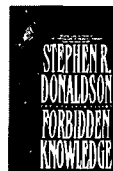
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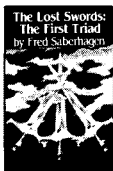
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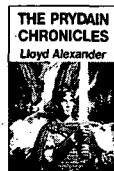
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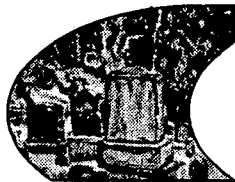
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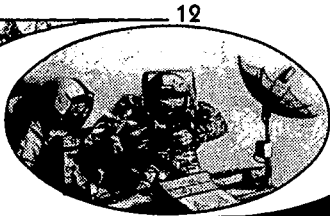
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September 1992

Next issue on sale  
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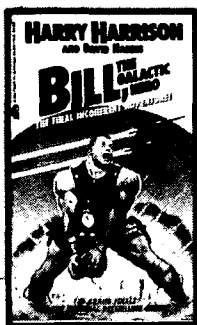
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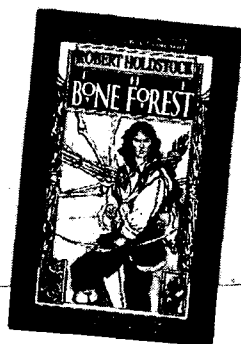
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## Editorial

# TWO-STAGE PROCESS

Stanley Schmidt

**M**any of the activities of civilized humans depend on two or more distinct operations being done correctly and in the correct order. If either is done badly, the entire venture fails. Often the two stages of such a process are done by separate people, so neither person or team alone, no matter how skillful, can ensure overall success. *Both* must get it right, or both their efforts are wasted.

For example, a sturdy house can't be built unless a good foundation is first laid, and then a good superstructure is built on top of it. Its various surfaces must first be properly prepared and then properly painted, or their finishes will not provide the esthetic quality and lasting protection that are their reason for being. If either the preparation or the final painting is faulty, it doesn't matter how good the other is.

Telegraphy is a relatively simple method of long-distance communication that can get a message from point A to point B even under adverse condi-

tions. But it's completely dependent on somebody at point A accurately translating the message into code and keying it into the transmitter, and somebody else at point B accurately translating it back into plain text. If the sender is sloppy, the receiver has only a garbled message. If the sender is fast and fluent but the receiver can't "read" well, the message is lost anyway. They *both* have to do their jobs well—which means both have to know what they're doing and concentrate on doing it well—or communication is not achieved.

I chose that last example with malice aforethought, because telegraphy is one method of communication—but the same principle applies to *any* kind of communication. Communication *per se* is one of the best imaginable examples of something which is inherently a two-stage, cooperative process. The two stages are always done by two different people (who are occasionally the same person at different times), and both

must do their parts conscientiously and correctly. Telegraphy is a particularly neat, clean example where it's easy to see the two stages and the importance of each. But it's just as true of writing a letter to your Aunt Maizie or reading one from her, or of writing or reading a magazine article.

In any such case, one person translates thoughts into words—symbols—which are conveyed to another, who then translates them back into thoughts. If they both do their jobs perfectly, the thoughts the second person gets from the words are the same ones the first put into them. But for that to happen, the two must have a finely tuned, shared understanding of what words mean. The speaker or writer must choose and assemble his words carefully to accurately express his thoughts. The listener or reader must pay careful attention to the words and the way they're put together to determine what thought they were intended to express.\*

\*Note to readers with hyperactive "sexism" detectors: To avoid becoming an example of what I'm complaining about, please read "he" as "he or she" throughout this essay. I'm explicitly defining it in the old, generic, nonsexist sense to avoid the awkwardness of repeatedly using three words where one will do. Sentences like the one preceding this footnote are cumbersome enough without adding unnecessary complications!

In other words, real communication happens *if and only if the writer or speaker takes pains to say exactly what he means, and the reader or listener takes equal pains to read or hear exactly what was said.*

Unfortunately, that all too seldom happens. One or the other, or both, botch it. A large percentage of human conflicts are caused by failures of communication. One person is careless about how he says what he means, and another, even listening carefully, comes away with a wrong impression. Or someone chooses his words very carefully, but someone else overreacts emotionally to one, ignores the rest, and winds up attributing completely inappropriate ideas to the speaker. Either way, communication fails, even though one person—half the "team"—tried diligently to make it work.

The problem is very familiar to writers. I've heard the complaint from every essayist or columnist I've ever heard touch on the subject: that no matter how hard they try to say precisely what they mean, some reader will read something completely different into it. Writers and editors, of course, are not always blameless. Not all of them put as much effort as they should into making sure they express their thoughts clearly and

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POSTMASTER: SEND to ANALOG SCIENCE FICTION & FACT (ASTOUNDING) P.O. BOX 7061, Red Oak, IA 51591.

IN CANADA RETURN TO 1215 WALKER ROAD, WINDSOR, ONT. CANADA N8Y 2N9

Editorial and Advertising: Analog Science Fiction & Fact, 380 Lexington Avenue, New York, NY 10168-0035

Subscriptions: Analog Science Fiction & Fact, P.O. Box 7061, Red Oak, IA 51591. ISSN 1059-9113

unambiguously, and sometimes even those who do try make a mistake. But quite often they do a good job, and still are misread. They organize their thoughts carefully, translate them into words with meticulous care, and still find readers getting completely wrong impressions. Sometimes such readers go even further and launch into fanciful rhapsodies of amateur psychoanalysis, "explaining" how the writer's opinions are obviously the result of this or that psychological hangup. In some cases they may be; but the assumption is not justified unless the reader knows the writer a lot better than he is likely to from an opinion piece or two.

Why do these things happen? Why are some writers unable to say clearly, precisely, and unambiguously what they mean? Why are even more readers

unable to read a paragraph and get from it everything the writer intended to put there, and nothing that he didn't?

After observing and thinking about the problem for many years, I've been forced to the conclusion that much of the blame falls squarely on the very institution which should be doing the most to prevent it: the teaching of English. This is not, I hasten to add, a blanket indictment of English teachers and curricula. Some really do further the development of communications skills both active (writing and speaking) and "passive" (reading and listening). But too many do not. Too many, in fact, are aggressively counterproductive from the standpoint of accurate communication.

In my own experience and observation, both direct and indirect, the more

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"advanced" an English course is, the more likely it is to actively encourage intentional obscurity in writing and wildly speculative sloppiness in interpretation. I was once told by one of my teachers that I had "wonderful insight" into poetry. Since on the whole I liked and in many respects admired this teacher, I didn't have the heart to tell her that what I really had wonderful insight into was what she wanted to read about poetry. It was easy, for me, to look at a poem and claim to find in it pages and pages of the kinds of Symbolism and Hidden Meaning she wanted me to see there. It was quite rare for me to believe that the poet had actually intended it, or that anything resembling a logical case could be made for that belief.

It seemed obvious to me that if we had to spend two weeks trying to figure out What the Author Was Trying to Say in a page of poetry or verse, he hadn't said it very well. That suggestion, however, was neither welcomed nor taken seriously in classroom discussion. The teacher would rather spend the two weeks and encourage the belief that what we were reading into the piece was true, important, profound, and somehow justified. When we were instructed to cite lines from *Oedipus Rex* or a Thomas Hardy novel as evidence that the characters' lives were controlled by Fate, the teacher would not even listen to an attempt to point out the crucial difference between evidence that their lives *were* so controlled and evidence that they *believed* they were so controlled.

In all these cases, in the name of Lit-

erary Analysis, we were encouraged and even required not to paraphrase or analyze what the author actually wrote, but rather to look at it and claim it said impressive-sounding things that it simply didn't. This is not careful communication. It is the antithesis of communication. Similarly, creative writing teachers often encourage their students to write in such a way that no clear meaning can be extracted from their words. They make a virtue of obscurity, perhaps because the more obscure a piece of writing is, the more fun the self-styled analysts can have reading nonsense into it, and the harder it is for anybody to refute them.

Again, this is not communication; it is "anticommunication." And in case any scientists or engineers are smugly applauding my harsh words to somebody else, let me point out that English teachers are not alone in this indulgence. Any group that can make a case for considering itself a highly educated elite is likely to cultivate obscurity to further separate itself from outsiders. A former academic colleague of mine told of a graduate seminar he'd taken in which the students took turns lecturing and being critiqued by other students and faculty members. A presentation of his was once downgraded because a questionnaire circulated among the listeners showed that fully 70% of them understood what he said. If that many of your listeners understand you, a professor explained, you are obviously speaking at too low a level. (Never mind the alternate explanation, that you were speaking at a good level but with

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# **C.J. CHERRYH**

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Now, I must acknowledge that some writers *do* deliberately incorporate complex symbolism and similar devices into their work, and that people are not always fully conscious of their reasons for doing things. However, in general I consider the author's opinion of what he was trying to say at least as reliable as the fabrications of somebody who doesn't even know him, and in most cases far more so. I have no particular objection to those who find such things amusing trying to guess what hidden meanings the author might have had in mind, or what unconscious motivations might have influenced him. But those who play that game need to be reminded bluntly and frequently that their guesses *are* guesses, and that it's inaccurate, unjust, counterproductive, and just plain wrong to believe that they are more than that. It's conceivable that someone with a death wish could have the thoughts and feelings in Robert Frost's poem "Stopping by Woods on a Snowy Evening." But there are so many other ways a person could be led to those thoughts and feelings that it's ridiculous to claim, as some have claimed, that the poem *says* he has a death wish.

If these fuzzy-thinking shenanigans and their effects were confined to classrooms, they would bother me less. Unfortunately, what goes on in classrooms has a substantial influence on how people function in the "real world." I see around me a world largely full of people who can neither write clearly and accurately nor read clearly and accurately,

when communication requires them to do both. I also see classrooms not only *failing* to develop these skills, but *actively* discouraging clarity and accuracy in both writing and reading. The connection seems clear.

If we are ever to have a world in which people understand and empathize with each other enough to work together on solving their common problems, they *must* learn to communicate. Since English and other languages exist primarily as tools for communication, classes in them are the obvious places to teach useful communication techniques and discourage harmful ones. This is not to say that there's no place in them for speculation about hidden meanings, symbolism, and unconscious motivations. But to the extent that they do those things, they need to make students aware that they *are* speculating and must not confuse their speculations with Proven Facts. They must explicitly recognize the possibility that what the author meant to say was exactly what he *did* say. And they must teach students to say exactly what they mean when they seriously want to convey an idea to another mind.

In short, I'd like to see less of our English teaching going into amateur psychoanalysis, and more into giving people the skills to both write and read accurately. So as a new school year approaches and English teachers—indeed, *all* teachers—begin thinking about their course plans, I hope they'll ask themselves: am I part of the problem, or the solution? ■

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#### PROLOGUE

##### *Daedalus Array: Lunar Farside*

For all practical purposes, Daedalus Crater was the most remote spot in the Solar System. Centered 180 degrees from the Earth-facing side and only 4 degrees below the lunar equator, Daedalus never saw or heard Earth, never received stray radio waves that might diffract over the lunar horizon and ruin delicate astronomical measurements.

Here in the orbital shadow, Daedalus crater was the perfect spot to station a Very Low Frequency array to study portions of the radio spectrum that were drowned out on Earth. Massive dipole antennas sprawled kilometers across the flat floor of the crater in a Y-shaped array, making the site look like a giant Mercedes Benz emblem encircled by the crater walls.

Because of its remoteness, the VLF site had to function autonomously. All instruments had been designed to run by themselves, to fix themselves with modular replacement parts, to be inspected by telepresence repair drones. With the unchanging nature of the Moon, the VLF should have operated for decades without human intervention.

Until absolutely everything went wrong.

Trevor "Can't Wait" Waite drew a stale breath from the cramped cabin of the lunar hopper as they approached the site. The hopper had been launched from Moonbase Columbus on an investigation and repair mission, and Waite fidgeted until he could go outside and have a look for himself. The scientists Earth-side were screaming about their

interrupted VLF data, and Can't Wait Waite could troubleshoot faster than anyone else on the base.

Unfortunately, even with 95 percent of the hopper's systems automated, outdated safety regs still demanded a full crew of three, with one person to remain inside the vehicle and two required on every extra-vehicular activity. Waite could have taken care of the problem himself in an hour or so; he was convinced that putting up with Sig Lasser- man's caution and Becky Snow's neo- phyte bumbling would triple the time required.

The hopper approached the lunar surface on the upper rim of Daedalus crater. It was difficult to see in the Lunar night. "I am taking her down slowly," Siegfried Lasser- man said. He spoke in a clipped German accent as he worked at the lander controls.

"Of course you are," Waite mumbled. He checked over his suit, anxious to be outside and tinkering with the malfunctioning antennas. *Let's get the show on the road!*

He hated to waste time sending a human to do a robot's job, but all the automatic sensors on the VLF had gone screwy, all the maintenance routines had failed, and no one could figure out just which branch in the endless fault-tree had been responsible for the breakdown. Two of the array's dipole antennas had blipped out within an hour of each other; a third quit less than a day later. The three defective units stood in a row, possibly signifying that the malfunction was spreading sequentially. And even worse, the repair drones would not respond.

Moonbase Columbus couldn't even

get a visual of the Daedalus site. Waite wondered if something as major as a meteor strike could have wrecked a portion of the array—but all the seismic sensors had been silent as fossils.

"Why is he setting us down up here?" Becky Snow asked, interrupting Waite's thoughts. "This wasn't briefed in the preflight." Her black eyes were wider than they should have been; perspiration glistened on her ebony cheeks and forehead.

Lasser- man's voice sounded clipped and professional, and his attention didn't waver from the controls. "To protect the array from any dust the hopper will kick up. The upper rim of the crater has an access road down to the floor. We'll be close enough up here."

"You'll see the array even in the darkness once we're down the access road," Waite said. Becky Snow had never been to the Farside before and had been on the Moon itself only five weeks. He hated being somebody's on-the-job training instructor.

Lasser- man set the hopper down on the landing area blasted flat behind the crater rim. He switched to a different set of controls, powering down the methane engines, as Waite and Snow twiddled their thumbs until their own work could begin. They wore their EVA suits though the hopper cabin was fully pressurized. Waite felt claustrophobic in the hopper, even with his faceplate flipped up. He wanted to be outside.

Lasser- man crouched by the hopper's instrument panel; his suit was linked to computers that projected data on a heads-up holographic display shimmering in front of him. "I am still getting anomalous readings from the EM

sounder. It shows something large and artificial out there, more than just the VLF. And the infrared response makes no sense. Much too high. It's been dark for ten days now—everything should be very cold."

"Maybe our dust is scattering the signal." Waite clicked down his faceplate and switched on the suit radio, impatient to solve the problem. Why talk about it anymore when they had come all this way to do a hands-on?

Lasserman hesitated. "*Dust should have settled by now,*" came his voice over the radio. "*That cannot be the explanation.*"

Waite finished checking his suit and moved toward the hatch. "Well, as soon as Becky's ready, we can go outside and have a look for ourselves. If nothing was screwy, we wouldn't have come all the way out here anyway." *If you weren't willing to take any risks, why did you come to the Moon in the first place?*

Startled, Becky fumbled with her own suit. Out of the corner of his eyes, Waite watched to make sure she went through the proper checks.

Lasserman nodded to his own controls, adjusting his throat mike. "*I am informing Mr. Dvorak that we have arrived and are still receiving anomalous signals. I will rig it so that they can observe the mission in realtime.*"

"Right," Waite said. As if the moonbase commander didn't have anything else to do. Or maybe he didn't. Jason Dvorak had been in command of Columbus for only a few weeks, and his promotion had surprised himself as much as everyone else, especially Bernard Chu, the former commander.

Maybe Dvorak did want to watch the repair activities.

"Ready," Becky said.

"Rog. We're going out now. Deploy the rover." Waite sealed the airlock and squinted at the blocky buttons on the control panel. A green READY light blinked at him. Pushing his space-suited thumb against the panel, he immediately felt his suit stiffen as the air bled out of the lock. A rush of warm air diffused through his suit as the heaters kicked on. Beside him in the cramped chamber, Becky Snow stood completely still.

"We'll get this straightened out in no time," he said for the benefit of the moonbase audience who would be watching the transmissions, and no doubt the hackers on Earth who loved to tap into boring moonbase jabber. The United Space Agency "Select" channel had long ago stopped broadcasting news about routine mission activities.

When the hopper's outer door unsealed itself, Waite climbed out of the airlock. He held out a hand to steady Becky as she climbed down the ladder, but she kept her own balance.

Turning, Waite paused to assess the distance to the VLF. The rover would kick up some dust, but that little bit shouldn't cause too much of a problem for the dipole antennas. Even in the darkness, through a breach in the crater wall, he could see the wide and crumbled access road left behind by the construction vehicles that had installed the array five years before. It would be a quick drive down.

"Don't spend too much time gawking at the scenery," Waite said to Becky. He turned to see that she had

already begun disengaging the rover vehicle from the hopper chassis. Lasser-  
man had deployed the package while  
they were still in the airlock. The lunar  
rover bounced once on the regolith and  
began to unfold.

"All right," she answered, and  
waited for him to get into the rover.

"We're heading out, Sig," Waite  
said.

*"Roger that. I am reading everything  
from your suit cameras. You are re-  
laying directly from the rover up to  
L-2."*

"Isn't realtime great?" He just hoped  
that the moonbase people wouldn't  
muck around with his job out here. He  
was the one on Farside, and he would  
make the decisions himself.

Lasserman would have preferred to  
sit wringing his hands until Dvorak or  
somebody else told him what to do, or  
maybe even until Celeste McConnell  
made a decision back on Earth. If he  
had to wait for them, "Can't Wait"  
could starve before they chose the  
"most judicious course of action."

Waite paused while the rover's steer-  
ing wheel popped out, then seated him-  
self on the vehicle's framework. The  
light banks came on, spilling out across  
the path ahead of them.

The Moon at night was full of shad-  
ows, but starlight undimmed by any at-  
mosphere glimmered down like ice-cold  
points. As soon as they passed over the  
lip of the crater, bouncing along the ac-  
cess road on the rover's wide tires,  
Waite saw immediately why the VLF  
array had ceased functioning. "There's  
something very wrong here," he trans-  
mitted, keeping his voice steady.

*"I can see that. Unbelievable!"* Las-  
serman's voice came into his ears. *"I've  
already checked in with Columbus.  
Somebody is going out to get Mr. Dvo-  
rak right away."*

That seemed unimportant to Waite.  
He stared down the sloping crater wall  
to the floor of Daedalus. Behind them a  
line of their own fresh tire tracks serpen-  
tined back toward the hopper.

Beside him, Becky leaned forward.  
"None of the archival photos looked  
like this."

"Those photos were two years old.  
You go ahead and gawk all you want."

In the starlight, he could see that two  
arms of the "Y" remained intact, but  
the third looked as if it had been bitten  
off. Directly next to the crater wall, a  
pit like a gigantic mine shaft plunged  
downward, three kilometers in diameter  
if it was an inch. It yawned like a giant  
mouth swallowing the floor, the VLF  
array, and every sign of human pres-  
ence. Waite could not see the bottom.

Spreading out in translucent strands,  
a wispy structure extended up from the  
pit, ghostly arches of fishline, support  
frameworks, silvery lines like a faded  
but complicated architectural drawing  
that had been mostly erased.

Becky Snow whispered, "It looks  
like the lair of one of those tunnel spi-  
ders. You know, with the spider waiting  
in the hole, and the web stretching out  
in all directions."

The sensor in his suit flashed warning  
lights to display his suddenly increased  
blood pressure and breathing rate.  
Scrubbers worked double-time to deal  
with the rush of sweat that had just burst  
from his body. Waite bumped on his  
chin mike, surprised to hear how steady

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his voice remained.

"Sig, can you see this?"

"*Only from your transmitter. I cannot see it from the hopper.*"

"That's because you're too far up, on the other side of the crater wall. You'd better make sure my transmission is getting to Columbus."

"*Rog. Your stereohip is still broadcasting to L-2. This is—*"

Waite cut him off. "I'm going to follow the access road for a while, go around the side to get a different perspective."

"*Be very cautious,*" Lasserman said.

"You can bet on it," Becky answered for Waite.

Waite eased the rover forward down the slope, which took him farther away from both the hopper and the structure. He wet his lips and looked down again to survey the hole. It was uncanny. He knew there hadn't been anything like this on the satellite recon photos, last taken years ago with the lunar orbiters. The Moon was geologically dead—there wasn't supposed to be any need to keep mapping the surface.

"How could you excavate a hole like that without making the seismographs yammer for days?" Becky asked.

"No way. You can't do it. The geologists should have been able to pinpoint the source to within a few meters. Those guys are a pain in the butt, but they're not *that* incompetent." After he had spoken, he realized he was "hot mike," transmitting everything back to the moonbase. Oh well.

As the rover continued its descent, Waite turned his attention to the other portions of the array, erected there by humans a few years before. The "spi-

derwebs" extended to the fourth dipole antenna on the array, draping the dipole.

Lasserman's voice burst into his ears again. "*Columbus advises that you do not go too close to the pit.*"

Waite was aggressive, but he wasn't stupid. "No problem."

He steered past truck-sized boulders and tried to keep out of the deepest shadows. With all the strange stuff going on, no telling what might jump out at him. The headlights shone ahead of him, calling too much attention to the rover. He felt like an intruder in a very dangerous place.

"*I am beginning to lose you on IR,*" Lasserman said. "*The background of that whole area is warm, quite a bit above normal.*"

"How the hell can it be warm?" Waite muttered to himself. Night on the Moon was so cold that it had taken years for spacesuit designers to come up with any systems that could cope with it. Before a long-time colony could be contemplated, NASA, ESA, and later the United Space Agency had to find new designs to tolerate the cold.

But the low temperature of the nighttime had nothing to do with the shivers running down Waite's spine.

Waite stared across the crater at the enormous pit. It reminded him of a strip mine that had appeared overnight, with no construction tracks, no seismic traces, and no debris. Still trying to convince himself it must be some kind of impact scar, he searched for ejecta, fissures, the swelling of a lip. But the hole was deep and black with an edge as sharp as a knife, giving up no hint as to where it had come from. It was sim-

ply . . . *there*. But who had done it? And in only a few years, max?

The diamondlike threads extended as far down inside the hole as Waite could see, then rose into the lunar vacuum in symmetric arches around the orifice. Only two of the nine arches met in the middle a good kilometer above the surface, like the petals of a gargantuan glass flower. A thin film of wispy material seemed to be filling the gaps between the lines. The rest of the arches still seemed to be under construction.

"*Trevor*," a new voice came over his suit radio from the moonbase, "*this is Lon Newellen. I'm trying to track down Dvorak right now. You'd better not get any closer to that thing.*"

"Fine with us, Big Daddy," Waite said. "You think this is going to be on Agency Select?" It was a joke to defend against his growing uneasiness. Nobody watched newsmag stories about moonbase daily routine anymore. "I'm wearing my good spacesuit."

The attempt at humor sailed past Newellen. "*What's your distance?*"

Waite looked around and guessed. "About half a kilometer from the edge of the thing."

"*OK, let me figure this out. If I can't find Jason, I need to check Earth-side. Director McConnell should know about this. Let her make the final decision. For now, why don't you go back to the hopper? Don't take any more chances.*"

Waite didn't argue, other than to grumble about who should be making his decisions for him. He found a wide spot on the access road, backing and filling until he managed to turn the rover around. Becky Snow kept her faceplate

pointed toward the structure below.

Waite pushed the rover's maximum speed, rolling on the balloon tires toward Lasserman and the waiting hopper, now five kilometers away. The access road was steep and winding, but getting farther from the crater floor and closer to the hopper made him feel safe. As they rose over the lip of the crater ten minutes later, the sight of the hopper eased his tension.

"*Ah, Trevor? Columbus?*" Lasserman said. "*I am getting some trouble readings here . . . a lot of them. My, my sensors are going wild!*"

"What kind of—"

"*Oh my God! I've got microleaks all over the place! Where are they coming from?*"

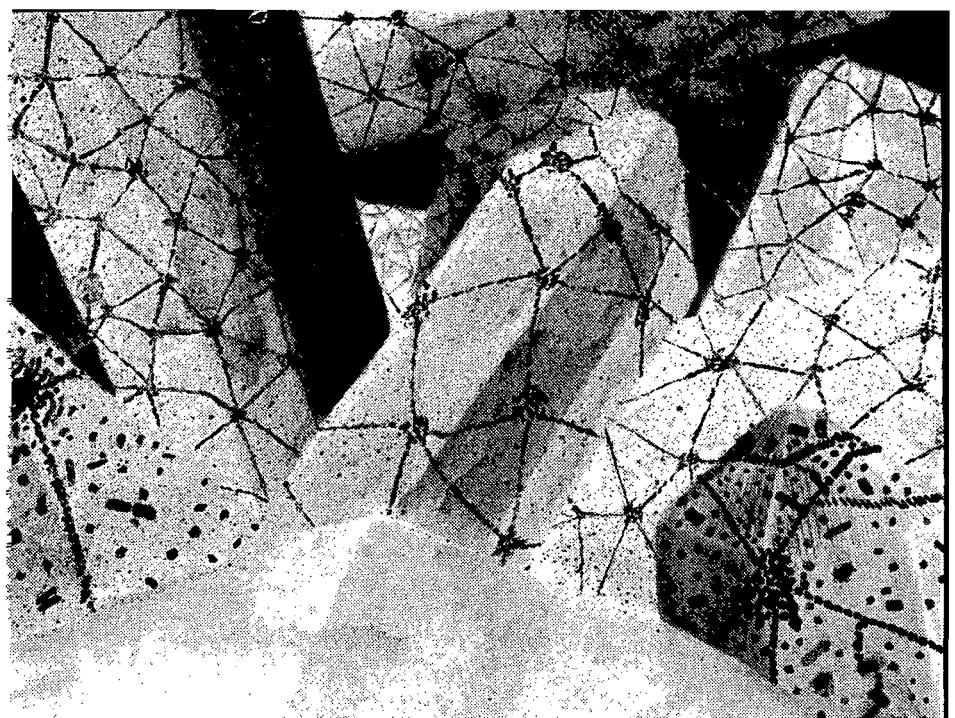
Waite increased the speed of the rover, as if that would do anything. Newellen at the moonbase transmitted again, asking for Lasserman to confirm his readings. Stupid!

"*My cabin pressure is dropping!*" Lasserman's voice jittered with panic. "*Hull integrity is—this whole thing is—disintegrating! I don't have a helmet on!*"

"Sig!" Waite shouted into his suit mike just as Lasserman screamed.

In front of their eyes, Waite and Becky watched as the hopper's body split open, gushing white frost as the ship's atmosphere exploded outward. Rocking from the force of the blast, the hopper teetered on its spindly legs. The hull crumbled, as if the metal had somehow turned into powder. The main body sagged and collapsed.

Becky was yelling. Waite shouted over the commotion. "*Columbus! Big Daddy, did you get that?!*" In the back



of his mind—the part not deadened with shock—he kept thinking *how are we going to get back? We're stranded out here on the Farside of the Moon. How long will it take them to send another hopper over? How much air do we have?*

He shook as he checked the rover's communication dish. The laser communications telescope still pointed to the L-2 relay satellite keeping vigil overhead. "Columbus. Columbus Base. Mayday, mayday!"

Becky kept shouting, but it was not mindless terror. "Trevor, I've got a puncture somewhere. My suit's leaking! I'm losing pressure—" She slapped at her suit.

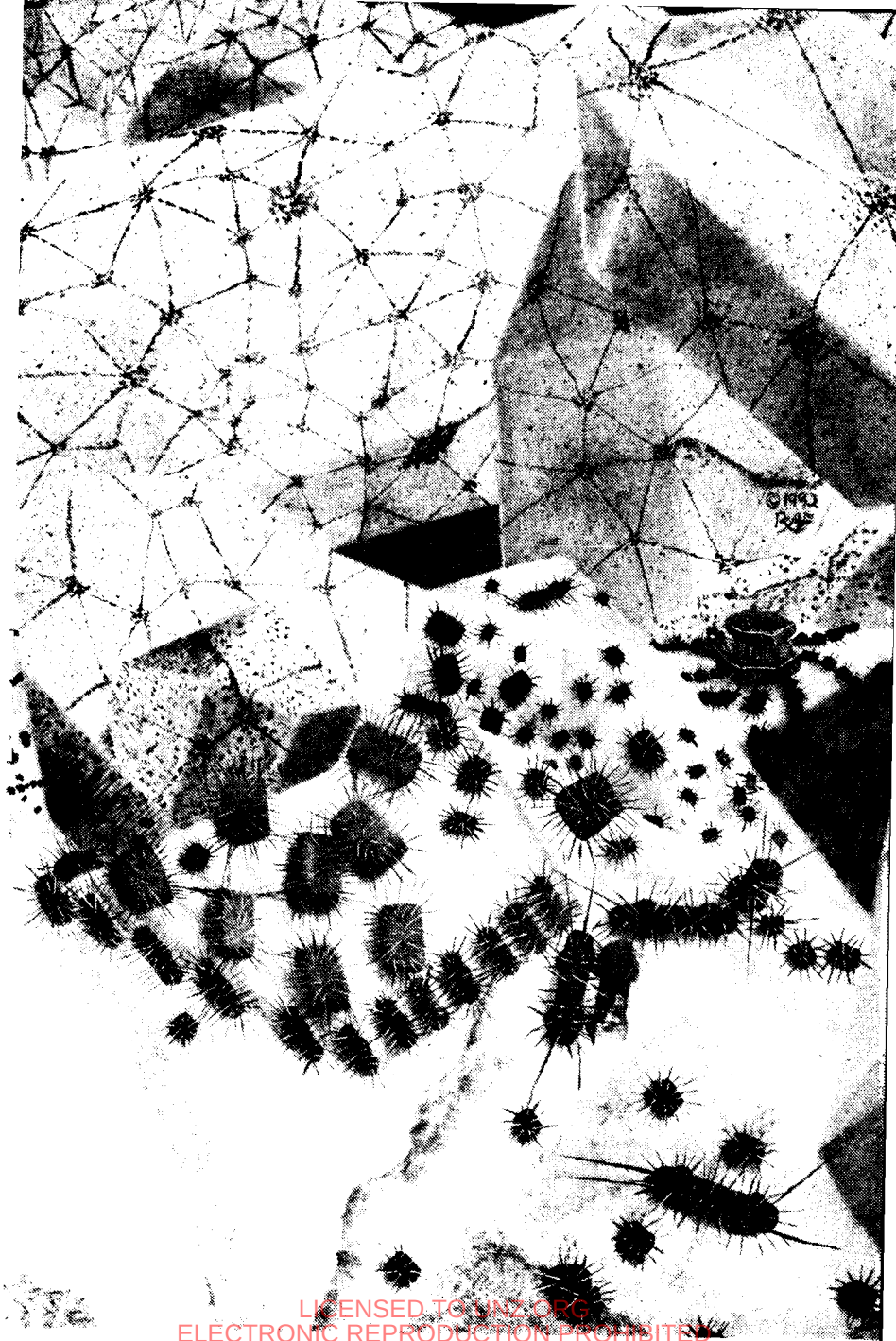
He could see the red telltales on the outside control pack. Every one of her suit systems was malfunctioning. She was standing up in the rover, flailing

her arms, pawing the chest control pack with her thickly gloved hands. "Trevor! My God, help me!"

He couldn't react quickly enough. How could everything go wrong at once? Then he noticed the metallic surface of her suit seething, boiling. He stopped himself from reaching out to touch her.

She made a choking noise over the radio, then suddenly a splash of blood splattered her faceplate. Explosive decompression killed her as vacuum breached her suit, dropping the pressure enough to make her head pop. Lifeless, sagging, she slumped over the side of the rover.

"Becky?" Waite's voice cracked. The horror froze his guts. He had to make a conscious effort to blink his eyes, to keep breathing. *My God, he*



thought. This couldn't be happening. Everything around him looked perfectly quiet and still.

All he could hear was the sound of his breathing; somewhere in the back of his mind someone was yelling at him over the radio. The hopper was gone. Lasserman was gone. Becky was gone. Some impossible structure had appeared in Daedalus Crater with no hint as to its origin. Becky had compared it to a spider waiting in its lair.

Then five telltale red lights winked on in his heads-up display, bathing his face in a glow like blood. Bitchin' Betsy, the voice-programmed chip, screamed, "Warning—your outer seal has been breached. Your suit is leaking at a rate of—". He stared down at his sleeves, watching the silvery coating foam as if someone had poured acid on it. Microleaks by the thousands sprang up through the suit, growing larger. His inner sealant systems made a valiant effort, but his entire suit seemed to be falling apart. Someone was screaming over the radio. . . .

Air rushed past his ears, and in an instant his eardrums burst. His chest pounded as vacuum ripped the breath from his lungs. Waite opened his mouth and a sheet of thin ice and spatters of blood covered the inside of his helmet. He tried to scream but then his visor dissolved.

He didn't even see himself falling to the lunar surface.

## CHAPTER 1

### *Moonbase Columbus*

The helium-3 processing plant looked like a lunar rover thrown together by a committee of abstract artists.

Standing two hundred meters away, Jason Dvorak recognized the large wheels and the heavily shielded nuclear power unit. Triangular heat radiators the size of old ship sails jutted up and out at an angle, giving the impression of a stegosaurus lumbering across the crater floor.

The front of the He-3 processor opened up in a cylinder of diamond-tipped teeth used for scooping and grinding the top layer of Moon dirt, or regolith; at the opposite end, a jumble of hot debris was deposited like excrement.

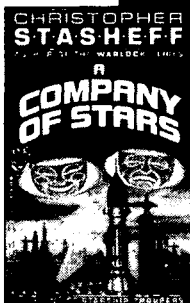
As the leviathan crawled along the surface, swallowing regolith, Jason felt pressure on his space-suited arm. He turned and, in a habit he could not seem to shake, looked at the reflectorized space-suit visor of his companion before glancing down to the name patch. *Never look at the face to recognize someone outside*, he kept telling himself. After a year, you'd think he'd be used to it.

Cyndi Salito's contralto voice came over his speaker. "You haven't moved for minutes, Jase."

"Can't help it." Jason turned back to the mobile processor. "I can't believe it's finally working. You beat your deadline by a week. This'll really look good for us. Especially for me—two weeks in command and already I have a major milestone to show off." *And it's a miracle the base hasn't fallen apart*, he added to himself. He still couldn't figure out why the space agency director, Celeste McConnell, had named him—an architect, of all people—commander. He was still getting used to the title.

SEPTEMBER

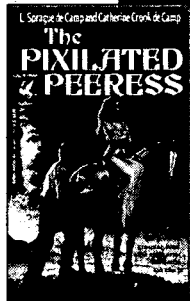
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"If it's working," corrected Cyndi. "The ten metric tons of dirt it's processing should yield a hundred milligrams of He-3. If the wizards back dirt-side keep their part of the bargain, we could have a working fusion plant by early next year. We're due to receive another proton transmission from the Nevada Test Site next month."

"I'll turn this place into a resort yet." Jason laughed.

"That's why you're up here, Jase," Salito said. Jason hated to be called by the nickname, but he never bothered to correct people. She nudged him back to their rover. "Come on, demonstration's over. If I was ten years younger, I'd take you out to dinner."

"You're just trying to make points with the boss," he said.

Salito made a sound like static on the suit radio. "Won't need to after next month."

"Columbus won't be the same without you all," he said. "I'm going to miss the crew."

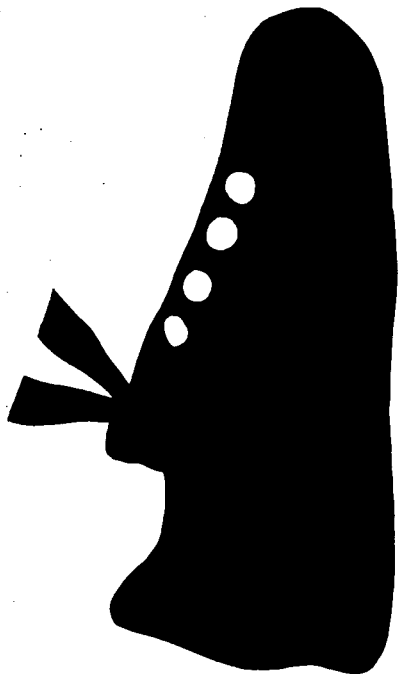
"You'll have sixty other people to keep you company."

Jason stepped over a rock as he climbed onto the rover's passenger seat, trying not to grip anything. Even at 4.5 psi suit pressure, the gloves still bit into his flesh. It was a common complaint. Fifty years of spaceflight and you'd think they could solve a simple problem of constant-volume suits, he thought. For months he'd put up with rubbing his hands raw each time he pulled off his gloves.

Salito started the rover and turned for Moonbase Columbus. "Aren't you looking forward to getting back to your wife? Seeing your twins?"

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"Of course," he said. That's what Salito expected him to say. But Jason's wife Margaret had filed for separation a month ago, before he had even been gone a year. Some devotion! Talk about twisting a knife 240,000 miles away. And his children, Lacy and Lawrence, hadn't seen him except on video transmissions since they were a year old. He was not looking forward to returning home. Being so far away put a little distance on the pain.

He tried to sound upbeat, for Salito's sake. "Hey, someone's got to put in that second level of habitation modules and make this base liveable, not a crummy boot camp. Can't trust a bunch of physicists and astronomers to get their hands dirty, digging tunnels and piling regolith. I watched how much trouble Bernard Chu had getting you all to put together the Sim-Mars base!"

Salito grunted over the radio; Jason had the frightening feeling that she saw right through his small talk.

Four groups made up the sixty person base, and everyone worked and socialized within their own group. Every six months a group rotated off the Moon, and a new one came on. After a year-long apprenticeship under Bernard Chu, who had transferred up to the Collins station at L-1, Jason had suddenly found himself the new commander of Moonbase Columbus. The change in assignment had surprised him as much as it had Chu. . . .

As the rover continued, Mare Smythi unfolded to reveal Columbus Base. The Earth hung low over the crater wall, like a big blue drop teeming with life. The tip of the base's sixteen-meter telescope was barely visible behind the embank-

ments of the buried living modules. From this vantage point, Jason couldn't see the optical interferometer, the gamma-ray telescope, and other astronomical equipment.

One of his first troubles as commander had been to placate the Earth-bound astronomical community by assuring them that the seismic vibrations from the wandering He-3 processing plants would not disturb any of the sensitive astronomical devices. No one using a Disney World telepresence link would be driving these monstrosities; the amusement parks used only little robotic rovers in a compound hundreds of kilometers away.

Jason had done that himself once, before he told anybody his dream to come up here. He remembered sitting behind the controls after waiting five hours in line at Disney World, marveling at how he could be driving a real lunar rover almost a quarter million miles away, just for the fun of it. He smiled as Cyndi Salito continued to drive to the moonbase.

As if a switch had been thrown, radio chatter filled Jason's helmet as they came into line-of-sight. "—not sure what happened. We lost contact with the hopper just before Waite's signal ended." "Get a hold of Dvorak yet?" "Still trying! L-1 can't raise him—"

Salito turned toward him, but Jason was already using his chin mike to break into the discussions. "Columbus, this is Dvorak. Big Daddy, what's going on?"

"Jason, am I glad to hear you! We were just going to send someone out to find you—"

Jason cut Lon Newellen off. "OK, I'm back. What's going on?" He barely

noticed Salito increasing the rover's speed.

"Trevor Waite's hopper—we haven't been able to raise it."

"Did the communication link fail?"

"No, that's not it. They . . . they were broadcasting from the VLF. Waite had gone with Becky Snow down into Daedalus crater and Lasserman was relaying the information from the hopper—" Newellen fell into an uncomfortable silence. Jason was about to press him, when Newellen spoke again.

"There's something more. You'd better get in here and see the visuals yourself."

Jason stood just outside the holotank in the control center. Two meters in diameter, the transparent cylinder took up the center of the hemispherical room. He placed a hand on the shimmering image and let out his breath. "Whoa. What the hell is that?"

Translucent spindly arms grew up from an impossibly deep hole next to the crater wall. A faint shimmer could be seen between the arms; two of them met in an arch half a kilometer up from the hole. The rest of the object seemed to be under construction.

The enormity of the scale made Jason take a step back when he caught a glimpse of the hopper landing zone, outside the crater. The hopper itself was destroyed. Trevor Waite, Becky Snow, and Siegfried Lasserman were dead. The first deaths on the Moon in years. And they were his responsibility.

But the mystery of the artifact kept grabbing his attention. The thing was huge—and no one had even suspected its presence.

"Flash up the most recent orbiter picture of that site." A cube dilated in the holotank, rotated. It showed the identical scene—without the hole and ghostly infrastructure. "When was this picture made?"

"That's from LO-3. That orbiter went down two years ago. Those pictures were taken just after the VLF went operational."

Jason stepped close and squinted at the images Waite had transmitted, but the tank's resolution got no better. "I can't make out any vehicle marks, except for Waite's rover."

"There weren't any."

Newellen pulled up his powder-blue jumpsuit and moved with balletlike grace in the low gravity toward the holotank. The heavysset man seemed out of place in the lunar environment; but Newellen's beefy frame was held up by some of the largest bones Jason had ever seen. People didn't appreciate the nickname of "Big Daddy" until they met the man up close.

Newellen jabbed a chubby finger into the shimmering 3-D image. "Way over here you can see plenty of places with rover tracks—here, here, and even here. These are all from when the VLF array was built years ago. You can even tell where some of the folks went off joy riding. But except for this isolated spot by the . . . the thing," he outlined the volume with a chubby finger, "The regolith is undisturbed. See." He punched at the holotank and the entire view collapsed to the spot he had outlined some seconds before.

Cyndi Salito pushed closer to the image, standing shoulder to shoulder with Jason and Newellen. "How come we

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didn't detect any of this before? What could have built that thing in the past two years without leaving any footprints? Has the regolith around the hole been swept back to cover tracks?"

"No way." Newellen magnified the image even more, and the ground took on a jumbled appearance. "We already ran a Mandelbrot simulation—we got the same distribution as what you're seeing here. The ground is essentially undisturbed."

No one spoke as he pulled the view back to encompass the entire structure. Jason kept staring at the image. "So what you're saying is that something the size of a football stadium just appeared out there, without any sign of construction, no by-products? That doesn't explain a damned thing!"

Newellen just shrugged. "Abracadabra."

"And Hopper-1—no idea of what happened? Or that last transmission from Trevor Waite?" Jason scowled and ran a hand through his dark curly hair. "Come on, damnit! Skyscrapers don't just start growing on the lunar surface!"

When nobody spoke for several moments, Newellen reran Lasserma's video transmission, relayed from Waite's stereochip. He stopped at the closeups of the gossamer structure rising from the pit.

Cyndi Salito finally broke the silence. "I'm not going to be the first to say the 'A' word."

Newellen rolled his eyes. "Right. Alien construction corps invades Moon. That'll rank right up with that statue of Elvis we're supposed to find on Mars."

Jason looked around to the other peo-

ple in the control center and narrowed his eyes. "I'm not going to be a laughingstock. But three people are dead, and we'll damn well find out why. Put me through to Director McConnell on Earth."

## CHAPTER 2

### *United Space Agency Washington, D.C.*

The general was in his element. Celeste McConnell could tell by his animated gestures and the emotion on his face as he strode in front of the sprawling holographic tank. He focused Celeste's attention on images of the asteroid as it tumbled toward Earth, an unstoppable island of rock nearly a mile across.

"Icarus is on an intercept course," said Major General Simon Pritchard. "It hasn't come this close to Earth orbit since 1968. These views are from the wide-field-of-view cameras on the orbiting Leansats." The window showed a potato-shaped Icarus rotating as it approached. It grew larger as the frames changed.

A picture of Earth filled another window as the general moved his fingers over the computer's controls. A moving bull's-eye scanned the Earth as the asteroid approached. Right then, the point of impact crossed Brazil.

"If we use the SpaceGuard orbiting defense system—" Just at the edge of the screen, Celeste could see a missile, streamlined and coasting outward, with the insignia of the United Space Agency perhaps too bright and prominent on its nuclear tip. The proposed SpaceGuard missiles were intended to be directed against space-borne threats.

Celeste smoothed her business suit. She still found it uncomfortable, even after all these years. But Washington, D.C. demanded a strict dress code. People wore ties and three-piece suits while relaxing in front of a fire. She had never gotten used to it. She preferred the comfortable zero-g jumpsuits she had worn as an astronaut, seven years ago now, while on the Grissom. . . .

Pritchard didn't look up as he reviewed the simulation. Two stars were prominent on each of his shoulders. She wondered what he would have been like as a college professor. Like most of the other PhDs she knew, Celeste suspected he had groomed himself specifically for her visit. He had set up the meeting weeks in advance.

Pritchard remained focused in total concentration. On the primary screen, Celeste watched a crater the size of a shopping mall appear over the asteroid's terminator as Icarus tumbled on its axis. SpaceGuard missiles streaked toward the craggy rock.

The situation here seemed surrealistic to her, a two-star general and the director of the United Space Agency alone in this control room. Pritchard had chased the techs and his aide away. He wanted to run the simulation himself; he had spent enough time training on the system.

"Missiles are incoming." Pritchard nodded at the image of Icarus. She could see the rock moving, changing, tugged by the steep gravity well of Earth. The nose of one of the SpaceGuard missiles tilted, and a targeting cross appeared on the surface of the asteroid. On the third viewing window, Earth rotated, placidly unaware of the

approaching threat.

"Course correction." Propulsion systems kicked in with a blast of silver-white vapor.

Pritchard's eyes were wide, enraptured by the events. Celeste tore her attention away from the screens to look at him, maintaining a professional expression on her own face. His medium-brown hair was tousled, a thin film of sweat holding it to his forehead. Wiry and sharp, Simon Pritchard did not look like a "Blood n' Guts" general.

"Ready, ready . . . impact."

Brilliant orange and yellow flared up on the screen showing Icarus as the missiles detonated. "Now, we've got two scenarios. Either the yield will be small enough to deflect the asteroid's orbit—" On another screen an orbital diagram appeared, showing the old orbit in red, intersecting Earth's position with an ominous X; then a new path in blue projected a more elongated ellipse that carried Icarus safely out of the bounds of Earth.

"—or it will be larger than the asteroid's tensile strength and fragment the asteroid into smaller pieces. And *that's* the problem. A lot of tiny chunks could hurt us more than the whole asteroid. So the trick is to have the missiles diagnose the asteroid while in flight, then change their yield so that the asteroid is only deflected."

Celeste put her hands on her hips. She stood several inches shorter than the major general. "If you can convince anyone to be worried about the threat in the first place."

"The probability of an impact is actually quite high," Pritchard said. "Right now, a kiloton of rock hits the atmos-

phere each year—and that's just a lot of small stuff. Icarus is on its way, after all. Watch."

The screen refreshed, showing an unaltered view of Icarus, still hurtling toward Earth. Celeste watched as the computer-generated views showed the asteroid tumbling end over end. It flared into brilliance like the Sun as it plowed into Earth's atmosphere, boiling steam from the air so that she couldn't see even the vaguest outlines of continents. It vanished into blood-red and orange as the model tried to show the impact.

"A couple of gigatons," said Pritchard. "Just like what hit the dinosaurs. We'd all be extinct, wiped out from the shock, from the earthquakes and tidal waves, or at the very least smothered over the long term by massive climatic disruption."

His gaze seemed to bore into her. Celeste felt uncomfortable, but she paid attention. Something about Pritchard's technique might be useful when she needed to convince members of Congress to support a pet project of her own.

Celeste folded her hands. She appreciated seeing this in a simulation room instead of enduring some boring lecture that had to be tailored to wide audiences and endless interruptions by aides and pagers.

With a jerk of her narrow chin, Celeste indicated the holography. All of the pictures had gone blank except for one, showing the globe smothered in gray clouds beneath which orange glows could be seen. "Is this a useful simulation, General?"

He raised his eyebrows, thought for a moment, then chose his answer.

"Icarus swings close to us every nineteen years. The error bars of its 2025 orbit are almost overlapping our path. An impact *will* happen—if not Icarus, then another one. We've squeaked by over and over again. I guess it just depends on how lucky six billion people feel. Are we prepared if it does happen? Most emphatically no."

Then Pritchard used a tactic she did not resent, though most other people would have been too frightened to bring it up. He said softly, "You of all people, Director McConnell, should not be comforted by the supposedly insignificant odds."

Celeste fixed him with a cold stare. She caught the slightest quiver in one eyelid. If she pushed, he would probably back down and apologize. But Celeste didn't want to do that.

The Grissom station had been wiped out by one such unexpected impact, by "space debris." Two people had died, one of them her husband Clark. Celeste herself and five others had been saved only through her quick thinking and what everyone else had called plain dumb luck. The incident had ruined her life, made her an international heroine, and, after rising up through the bureaucracy, had eventually led to her appointment as director of the United Space Agency. Few people were willing to mention that part of her past; Pritchard, though, pulled no punches.

"I admire what you're doing, General. I really do. And in me, you have a sympathetic ear. I especially appreciate your candor. I have to put up with enough bull in twelve committee meetings a week.

"But now I must be honest with you.

Regardless of the Icarus threat, whether perceived or real, your SpaceGuard defense system is not something I can sell to Congress. Nobody wants to hear about space-deployed missiles. Nobody wants to even think about them—even if we need it.”

The general set his mouth. “I didn’t calculate the probabilities that we’d be hit, Ms. McConnell. It was *your* people that approached us for a solution.”

Celeste reached across the table, palms up. “I realize that. But in the current political climate, even if the Icarus impact were an undisputed fact, it still wouldn’t do any good. Nobody wants to hear about a threat from space. No matter how bad it is.”

She beamed a smile at him. “Forget about Icarus, General. According to mythology, Icarus was a fool who lost his wings and crashed into the sea. Daedalus, though, was the interesting one who created dazzling new technologies. Come with me—let me show you exactly how interesting Daedalus has become.”

Celeste took Pritchard past the two stone-faced guards into the Agency’s Mission Control. The two guards, a young Japanese man and woman, scrutinized Celeste’s badge, though they had seen her a thousand times before. But recent terrorist threats by an EARTH FIRST! group had forced increased security. Before either guard could object to the general’s presence, Celeste raised her hand. “It’s all right. I’ll vouch for him.”

Pritchard started looking around before the reflectorized booth door closed behind him. Celeste saw his eyes

widen. The local Mission Control was drastically reduced compared with the old Mission Control centers from the days of the Shuttle missions. Because of advances in neural networks, distributed processing, and sheer computing power, the United Space Agency did not need a room the size of a giant auditorium staffed by a small army of personnel to run various missions—a handful of people in a large meeting room sufficed.

While Pritchard gawked, Albert Fukumitsu, the duty manager, waved her over. “Director McConnell, we’ve been trying to track you down!” He wiped sweat off his forehead. He had shaggy black hair tucked behind a headband. “Jason Dvorak keeps calling from Moonbase Columbus.”

“I had my pager shut off,” Celeste said. She had enjoyed her few moments of peace enough to make the headaches of being out of touch worthwhile. “Jason needs to stop panicking and handle a little more himself.”

Fukumitsu looked at her with a wry, skeptical expression. “This is a somewhat unusual circumstance.”

“Agreed. Did he launch the telepresence probe on schedule?”

“Yes, an hour ago.” He waved his hand toward the screens on the wall. One of the technicians, eavesdropping, called up a file that showed the sequence of the hopper rising up in a puff of methane. “ETA at the Daedalus site in about ten minutes.”

“Long enough to get Jason on-line.” Celeste pulled up one of the chairs vacated by an off-duty tech and sat down beside Fukumitsu. “He’s probably fidgeting like a new father in the hospital

waiting room.”

She still smiled at how unlikely being in charge must seem to Dvorak, and she certainly couldn't explain to him the reasons behind her unexpected decision to place him in command.

Dvorak was an award-winning, innovative architect; he had grown bored with the mundane work on Earth after having designed the impossible a dozen times over. Then he had used his connections to get himself an audience with the director of the United Space Agency. When he sat down across the desk from her, Celeste had had no idea at all why he wanted to see her. But when he began to spill his idea about revamping the entire moonbase, getting it ready for the next explosion of inhabitants, Dvorak had won her over. “They are our pioneers,” he had said. “Right now they’re living in flimsy tents. Let me give them log cabins at least.”

She had approved his training and his assignment, and after nearly a year on the moonbase, scoping possibilities, reconfiguring some of the living quarters, Jason Dvorak had already made his mark on daily life up there. Without giving him any preparation time, she had rotated the former moonbase commander, Bernard Chu, up to the Collins waystation at L-1, while sending the Collins's former commander, Eileen Dannon, back Earthside, where her frequent disagreements with Celeste could be covered up more easily.

At first, Dvorak had reveled in his dream-come-true assignment, but at times like this he was proving to be too much of a nice guy to make tough decisions under stress. Maybe Bernard Chu would be better off back down on the

Moon, at least for the interim . . . ever since the Grissom disaster seven years before, he had supported her in everything she asked.

But no, Jason Dvorak had only been in full command for two weeks now. He deserved more of a chance.

“Let me see Waite's pictures,” she said. Fukumitsu nodded to one of the techs, who worked on pulling up the images.

General Pritchard came up beside her, relaxed in his Air Force uniform. “Daedalus—that's where some of your astronomy equipment is stationed on the lunar Farside.”

“That's right.”

The image of the crater as seen from Trevor Waite's viewpoint appeared. “Zoom in,” Fukumitsu said.

The images of the Daedalus anomaly resolved themselves on a large window that blossomed in the center of the wall. Unlike the general's computer-generated graphics, though, these images were real. She felt her skin crawl with an eerie foretaste of what would be in store for the world as soon as they understood what was really happening on the Moon. She had had nightmares about this.

“We're still analyzing the situation,” Celeste said to Pritchard, “but I hope we know something new in a few minutes.”

On the screens, they saw close-ups of Daedalus, its flat crater floor dominated by pieces of the VLF array and the smooth-walled pit covered with a translucent framework of the main structure. The white lines looked like an architectural sketch, a 3-D blueprint that had somehow appeared but had left no de-

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bris, no seismic signatures, no obvious clues as to its origin.

The general seemed to comprehend that this was something far more bizarre than he had expected. "What is this? Where did it come from?"

At that moment, the main portion of the videowall was supplanted by a too-close image of Jason Dvorak. His brown eyes were bright with fatigue, his dark curly hair mussed, but his lips had a persistent upturn that always made him look about to break into a grin. He stepped back into better focus.

"Director McConnell, I was beginning to wonder if you'd be here to witness the probe."

Celeste smoothed her trim business suit and stood into prime focus. She was petite, but carried a powerful presence. Her eyes were dark enough to look like black lacquer. Newsnet profiles insisted on calling her the Ice Lady. She spoke softly, letting her voice carry a chiding tone, but not enough to jeopardize her working relationship with Dvorak.

"Jason, I agreed to be here, but I didn't promise to be early." After a half-beat of silence, she continued. "This is Major General Simon Pritchard. He's here to add his thoughts. Perhaps together we can figure this thing out."

Pritchard nodded with surprise, but he recovered quickly. Holding a conversation from the Earth to the Moon with its resultant transmission lag was a bit like a drunkard's walk, two steps forward, then a pause to catch bearings, and then another two steps forward again.

Dvorak looked off screen. He nodded, then said, "Switching to the cam-

eras on the hopper." The view expanded to take in a group of people clustered around him.

A large man next to Dvorak called up a holographic control panel that hung in the air in front of his hands. Other technicians in his cramped control center called out numbers and sent readings down to Earth. The window showing Dvorak's image receded to the upper left corner, while new windows opened to display telemetry, a CAD animation showing the attitude of the hopper, and a rotating globe of the Moon displaying trajectories with a targeting cross over Daedalus crater on the nightside. The largest window on the viewing wall opened up, showing Daedalus as it grew larger each second. Already they could make out the mysterious gossamer structure of the anomaly.

As the hopper flew over, Dvorak refrained from commenting, which Celeste appreciated. Nobody knew what was going on here anyway.

Pritchard drew in a breath as the hopper's medium-resolution camera showed the arcs rising from the dust, the framework of a huge bowl, impossible lacy girders that seemed to have no support whatsoever. It looked as if some gigantic being had played cat's cradle in the middle of a crater.

"OK, getting some readings now," Dvorak said. "X-ray backscatter shows the materials are extremely hard and light, not very dense. Like an aerogel, except made out of diamond fibers. Maybe it's like the diamond foam they're trying to fabricate in the orbiting labs."

Celeste nodded. Dvorak's voice took on a trace of alarm. "I'm detecting no

sign of my crew. Nothing. There should be a rover and a hopper. Not to mention three bodies, three suits. Where the hell are they?"

"What is he talking about?" Pritchard asked. Speaking in a rushed whisper out of the corner of her mouth, Celeste filled him in on the details about Waite, Lasserman, and Snow.

"But how did it get there?" Pritchard said without taking his eyes from the display. "Look at that pit—to excavate that would have required a few megatons of energy!"

Celeste had forgotten about Pritchard's background as a scientist. "I know. But we detected nothing. I can show you all the traces. The Moon is a million times less active than Earth, and we should have at least seen something. But no seismic activity near Daedalus."

The autopiloted hopper flew over the wide pit. *Was this some surreptitious lunar mining operation? Ore pirates?* The thought was so ridiculous Celeste was glad she had not said anything aloud. Even under the dim night-side illumination, the depths of the pit looked as black as tar. If anybody was still working down there, they used no lights.

"Could they—" the general paused, emphasizing the word "they" as if afraid to suggest what he might be thinking; Celeste had already begun arguing with herself about the same thing. "—I mean, could your seismic network have been scrambled somehow? The traces erased?"

"Either that," she said, "or they found some way to excavate that pit and erect those frameworks without causing a jitter."

"Impossible, isn't it?"

"General, the entire thing is impossible!"

Dvorak interrupted. The CAD viewing window showed the hopper flying away from the pit. They had opted to use all of the vehicle's fuel to survey the site completely and to forego a return flight. "Maneuvering fuel is getting low. That's about all the overhead reconnaissance we can manage if we want to guarantee a safe landing."

"Set the hopper down," Celeste said.

"Go to one of those tower structures," Pritchard suggested.

As the hopper settled down on a flat tract of regolith, Celeste could see the sharp-edged tread marks of one of the lunar construction rovers that had erected the VLF array three years before. The base of a ghostly tower rose seamlessly out of the soil, cutting in half the footprint some worker had left behind. Dust from the hopper's landing clouded the black sky.

Spotlights shone up into the weblike arches. In the upper-left corner of the viewing wall, Lon Newellen played with the telepresence panel. The probe deployed its instruments.

"I'm getting no motion anywhere. Not a tremor, not a heartbeat, just a few jitters left over from landing. This place is as still as a statue."

Somehow the image reminded Celeste of the great Egyptian pyramids, or the sphinx, or some long-abandoned temple erected at the dawn of time. But this was not old. She kept reminding herself of that.

Data from electromagnetic sounders, mapping spectrometers, chemistry,

mineralogy, topography, and gravitational sensors scrolled down their own windows at the bottom of the viewing wall, but Dvorak interpreted them. "Not seeing any radiation, no detectable energy surges, but the area temperature is about seven degrees hotter than we can account for. I keep getting ultra-transient blips on the gamma-ray detectors. Too brief to contain any information. I would try to explain them away as glitches, but they're confined to a very discrete energy range. That doesn't make sense."

The image on the screen jerked with a blast of static, then refocused. The static returned, worse this time, and the picture did not wholly recover. The image skewed, with video distortion and graininess. Then the camera swung sideways, as if someone had bumped the entire probe.

"I'm not doing that!" Newellen said, holding his hands up as if to display his innocence.

Several of the probe instruments blared error messages. Two went blank.

"Turn the camera to look at the ground," Celeste said.

Newellen's own answer overlapped hers in the transmission lag. "Something's screwing with the electronics. Failures are showing up everywhere." The image jerked, as if some piece had just snapped off the supports. But Newellen managed to swivel the camera around, zooming in on the spiderlike leg of the probe.

The gleaming gold surface showed grainy pitting. As she watched, Celeste saw it fizzing like foam.

"The whole thing is disintegrating!" Dvorak said.

The hopper canted, then toppled over on its side. The image swung wildly to display the silent, gossamer towers stretching toward the stars. Then all the windows on the viewing wall filled with a thunderstorm of static before Fukumitsu closed them, bringing Dvorak's image back into the primary position.

"I don't know what else we can do," Dvorak said. "No radiation bursts, no energy surges. I didn't detect anything that could have caused this!"

"All right," Celeste tried to sound soothing to cover his alarm. "I want you to try again. If it's radiating in the infrared, I want an IR flyover. Put a new sensor package into those javelin probes you've been deploying to take remote core samples for the geologists. Next time, arrange for a sample-return mission."

"We need a closer look," the general said.

"I'm not going to send a person out there. I've already lost three people, and now this probe," said Jason.

She paused to ponder her options. "No, we can do it remotely. Something in the area itself seems to be disintegrating our machines. We've got to grab a chunk of that regolith, then return. But I don't want to risk contaminating Columbus if it's something in the dirt. You can set up an isolated laboratory in the Sim-Mars module—that should be far enough away from the moonbase to keep you safe."

Dvorak spoke again, sounding formal now, "I don't think I have the facilities here to do much, Director McConnell. We aren't a full-fledged research station, you know."

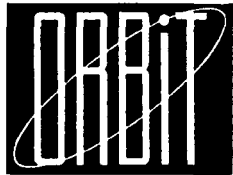
She sighed. "I'm going to gather a

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team of experts to help you out. We'll even send them up if need be, but we need to know more before I can choose."

Dvorak nodded, still looking overwhelmed, but a bit more relieved. "All right, but I think it's time we go public with this. Waite, Lasserma, and Snow deserve that at least."

"I agree. I have no intention of keeping this a secret," Celeste said. "No intention at all."

After Dvorak had signed off, General Pritchard remained grim faced. Celeste placed a hand on his shoulder, which startled him. His uniform felt crisp and uncomfortable beneath her palm. "Well, General, how is that for an outside threat? I don't think you need to continue your Icarus scenarios. Do you think we can stir up a little interest now?"

### CHAPTER 3

#### *Antarctica—Nanotechnology Isolation Laboratory*

Low-angled sunlight pooled through the passive-solar heating plates of the Nanotech Isolation Laboratory. Dr. Jordan Parvu smiled to himself as he stared at the images of his four grandchildren. They rubbed their eyes and waved to him. Parvu had forgotten that it would be the middle of the night when he called his son, but Timothy had rushed to wake up the children. As busy as he was with his work and with the perpetual daylight here in Antarctica, Parvu sometimes forgot the natural daily rhythms of other people.

The NIL's optical uplinks and the big viewing screen were supposedly used for teleconferencing, data transfer, and

occasional remote-presence experiments from other nanotechnology researchers across the globe. But no one would begrudge him an occasional personal call. His only assistant, Erika Trace, rarely used her own allotment.

Timothy seemed at a loss for words and didn't know how to keep the conversation going. Parvu himself didn't need to say much—just looking at his family made him feel warm inside.

Parvu could see an image of himself in Timothy's face: the sharp nose, the thick hair that before long would turn to a uniform iron gray, the bushy eyebrows, dark eyes with a fan of laugh lines around them, deep brown skin, and bright teeth in a perfect smile.

Erika Trace burst into the teleconferencing room. "Jordan—I mean, Dr. Parvu," she amended quickly, seeing him speaking to his family, "we're ready to install the new prototype nanomachines. I've got the canister and the nanocore prepped." She wore her blond hair in a serviceable cut, long and plain with no particular attention to style. Her greenish eyes looked darker in the low sunlight.

"Ah, excuse me—" He turned back to Timothy and was surprised to find a disapproving expression on his son's face. But Erika had never shown any sort of attraction toward him—thank goodness! Passion for her work consumed her. That sort of obsession shouldn't come until later in life, Parvu thought, after one had spent time living. He hoped Erika learned that before she had wasted her youth.

"I must go now, my son, my grandchildren."

"Wave goodbye now," Timothy

said. In unison, the four children flapped their hands and giggled. Parvu signed off. The blank screen always made him feel hollow.

Parvu and Erika departed through the set of double airlock doors. As he cycled through the second door, Parvu felt the wind stream past him. The air pressure increased by 20 percent through each of the doors to eliminate any chance of nanotech contamination and migration.

He passed through the airlocks into the NIL dome itself. The entire outer third contained the teleconference room along with the main computers, power generators, file storage, a small cubicle containing the test animals, terminals, and working areas. Inside a thick, doubly insulated wall was the main clean-room area.

Parvu rubbed his hands together; eagerness to analyze the new specimens made him fidget. They had been waiting for weeks. He wanted to contact Maia Compton-Reasor and her team at Stanford, then get in touch with Maurice Taylor's team at MIT. Together, they would begin the first analysis. Combined research had been developing these new specimens for months, but they could not go forward with active automata except down here in the secure NIL.

Garbed in her clean-room outfit, Erika prepared the black canister next to the cylindrical shaft of the nanocore that rose to the ceiling. She would have checked everything several times and made the initial optical linkup request with MIT and Stanford. Parvu would do the sample transfer himself.

As he entered the second set of air-

lock doors into the laboratory dome he stopped to don a plastic cap, a lint-free smock, and booties over his slippers. He pulled thin rubber gloves over his sweaty hands, then stepped on a pad of gray stickum before he passed into the lab room itself.

Erika bustled about. She was always so dedicated to him, to their projects. When she had met him, Erika had been one of Taylor's students at MIT, with a background in physics and integrated-circuit fabrication techniques. In her, Parvu had discovered a kindred soul, and they worked well together. Erika had begged him to take her along when he left MIT to work for the Center for High-Technology Materials in Albuquerque. He wondered why he deserved such a devoted acolyte.

"I've got everything ready. Taylor is out of reach, probably on his way into campus. They've summoned Dr. Compton-Reasor. She was asleep, I believe, but had left word to be called whenever we got in touch."

"We will need Dr. Taylor's code to activate the samples," he said.

"He's on his way." She lowered her voice. "He always manages to be late, no matter what the situation is."

"Just so," Parvu said, then moved to help her.

She had mounted the sample canister to the access port on the transparent shaft of the nanocore. The seals were locked; all the fail-safe contacts had automatically engaged. If anyone tampered with the seals on the canister, the interior would be sterilized by an incinerating charge. The nanotechnology samples inside were dormant, left purposely incomplete. A code from Maia

Compton-Reasor would initialize them; a second code from Taylor would activate them. Only Parvu could open the seals to let the prototypes into the nanocore.

Rising to the depleted-uranium shield on the ceiling of the NIL dome, the transparent nanocore was filled with a clear resource solution. Within the core were microwaldoes, precision-guided lasers, stereo microscopes, electron microscopes, scanning x-ray microscopes, and a low-energy collimated particle beam. A strong electrostatic current ran on a conductive film just inside the nanocore walls as a barricade against the tiny machines.

But the main defense against escaping samples came from capacitor banks beneath the dome; they powered the coaxial conductor running through the nanocore to a high-Z target on the roof. As a last resort, if the automata breached all barriers, the capacitor banks would discharge, sending a magnetized plasma ring through the central conductor to slam against the uranium shield. An immense shower of x-rays would flood the entire NIL, sterilizing everything . . . and killing everyone inside.

Parvu had insisted on the defensive measures before agreeing to head the NIL work. He knew how threatening runaway self-replicating automata could be, and so did the other nanotech researchers around the world. Most of the public didn't quite understand—which was fine with Parvu—yet he did not want to take any chances. The fail-safe systems in the NIL, and its isolation in Antarctica, would allow him to work with confidence.

Oddly enough, Parvu had never

thought his major supporter would be the United Space Agency, but when Celeste McConnell had pitched to him her incredible proposal for terraforming Mars, his imagination had ignited with the possibilities. He imagined generations of self-replicating automata seeded on the frigid surface of Mars, spreading out across the iron-rich sands.

Their programming would be simple, with no mission other than to liberate oxygen molecules in the rocks and to shut down when the partial pressure reached a pre-set level. Satellites transmitting an ABORT code could stop the oxygen production at any time, if human command-and-control made that decision.

Given the speed at which the oxygen nanominers could reproduce, Mars could theoretically have a breathable atmosphere in a week. *A week!* Parvu knew that there was another lab, nearly identical to this, waiting on the surface of the Moon if they were successful here . . . but it would be another two years until that became operational.

The teleconference screen chimed and an image of Maia Compton-Reasor appeared. She was a squat African-American with sleepy eyes and hair cropped so close to her head it looked like felt. "Dr. Parvu? Dr. Parvu are you there?"

Erika had disengaged the SEND half of the loop, and Parvu toggled it on. "We're here. We've just received the samples. Sorry to wake you."

She dismissed the comment with a wave. "I can sleep anytime. Are you ready?"

"Nearly so. We are still awaiting Dr. Taylor's response."

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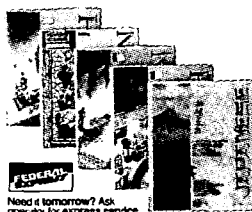
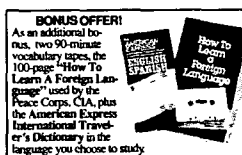
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Compton-Reasor snorted. "We always have to wait for him."

Erika fidgeted in the lab space. Parvu noticed she had slid to the side, out of the screen's field of view. She never wanted to take the credit due her. He would have to insist that she begin acting like his partner instead of an assistant. She deserved that, whether she wanted it or not. He had already put her name as first author on a handful of journal articles, without telling her.

"I think you'll find these are the most promising nanomachines yet," Compton-Reasor said. "If this pans out, it opens a whole new line of development."

For decades, researchers had been investigating techniques with scanning tunneling microscopes to build nanoframeworks, ballistic electron emission microscopy to etch templates for even smaller circuits, collimated neutron beams to chisel out gears and rods less than a millionth of a meter across. Other researchers worked with protein engineering, trying to program organic machines.

In addition to the Stanford and MIT work, recognized research efforts at Cambridge, Tokyo, and a European consortium in Belgium bought time in the NIL facilities. Parvu often felt himself in the position of the caretaker of a world-class telescope while visiting astronomers squabbled over observing time.

The Stanford team had designed a new organic and mechanical prototype, assembled in part with protein engineering and in part with micromechanical parts. In tandem, Taylor's team had developed software that could make

these machines function as miraculous analytical tools. Ideally, they would be able to take apart a sample, analyze it, then broadcast data detailed to the molecular level back to receiving computers.

With the new prototypes in hand, Parvu dreaded the thought of an hour of aimless chit-chat with Compton-Reasor while waiting for Taylor to show up. But before they could attempt to make small talk, Taylor responded. The receiving screen divided the imaging area in two and displayed Maurice Taylor's flushed face looking more like that of a football player than an award-winning researcher. He wasted no time.

"Sorry I'm late. We had no idea when the package would arrive." He fumbled at a keyboard off the boundary of the screen. "Well, Erika, nice to see you again. Jordan. Are you ready? I can transmit now."

Compton-Reasor began a sharp response, but Parvu muted her half of the screen and nodded politely. "Yes, if you please. Everything else is prepared."

Erika went over to the nanocore. Parvu waited until Taylor had sent his portion of the activation code. An embedded green light, previously hidden, glowed on the smooth side of the black canister.

"Very well, I will now open the environment to the nanocore." He entered the encrypted key sequence to the self-destruct seals. The canister gave a dull click. Parvu knew that inside, the dormant machines had been flushed into the absolute isolation of the core. He resealed the lock and removed the empty canister. It would be bathed in

# **I** *t began when Morn Hyland came into Mallorys Bar and Sleep*

*with Angus Thermopyle...*



*She was gorgeous.*



*In contrast, he was probably the most disreputable man who still had docking  
rights at the station.*



*No one was surprised by the current which*

*sparked across the crowd when she and Nick Succorso*



*first spotted each other.*

*They left together to become the kind of story drunks and dreamers told each other when Mallorys was quiet  
and the thin alloy walls seemed safe against the hard vacuum of space and the luring madness of the Gap.*

*That, of course, was not THE REAL STORY...*

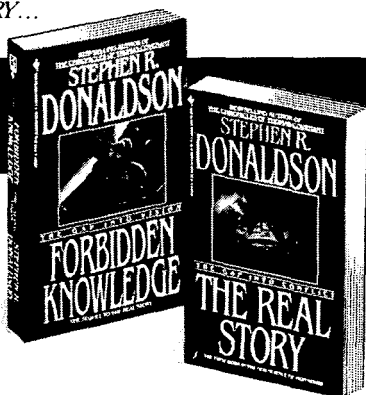
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x-rays and then slugged.

"Secure." Now, Dr. Compton-Reasor, would you do the honors please? The second half of the activation code."

Erika leaned close, peering into the curved transparent wall of the nanocore. Parvu could tell by the stabilization readings that the microwaldoes were drifting in a slight current caused by the introduction of the new samples.

"It's sent," Compton-Reasor said. "Everything's underway."

It was all very anticlimactic. The new samples—so small that tens of millions of them could line up and still not cross a centimeter mark—could not be seen inside the resource solution. After days had passed, he and Erika might be able to discern a cloudiness in the fluid caused by so many tiny bodies.

"Congratulations, all around," Compton-Reasor said. "I hope you and Ms. Trace have some champagne with you."

"We'll make do," Parvu said, smiling.

"I'll monitor the progress," Erika said.

"Then I'm going back to bed," Compton-Reasor said. She waved a dark hand and signed off.

"Let us know if anything happens," Taylor said, then his image winked off.

The Nanotech Isolation Lab remained totally silent. Parvu thought he could hear Erika breathing. They were both smiling. Something about these new prototypes seemed promising. He had high hopes for the project, and for the terraforming of Mars.

Inside the nanocore, the tiny prototypes, newly awakened, began to self-replicate, using raw materials from the

solution around them. Soon they would go about their work.

## CHAPTER 4

### *Moonbase Columbus*

The nightside of the Moon was so cold that the extra seven degrees of heat around Daedalus showed up like a spotlight in infrared. The IR trace was a perfect circle glowing scarlet in false-color intensity.

Centered exactly on the gaping pit, the residual heat in the ground extended about three kilometers out. On the holoscreen, black data points showed where Lasserman had landed his hopper, where Waite had driven his rover, where the telepresence hopper had landed. All of them fell right in the middle of the red circle.

"We need a sample of regolith from inside that hot zone, but anything we send there gets eaten up," Jason said. He raised his eyes to the other people in the control center. "Suggestions anyone?"

He glanced over at Big Daddy Newellen. The man shook his meaty head; behind him, Salito stared into the holotank. Nobody met Jason's eyes. "Come on, people!"

"Well," Newellen said, twisting his lower lip with two fingers, "that all depends on the answer to another question. What's really going on? Is there a disintegrator ray out there, zapping anything that happens to trespass on the construction site? Or is the regolith itself impregnated with acid or infested with some kind of bug that's taking our stuff apart? Either way, how do we get hold of a specimen to look at?"

"How do you pick up a universal sol-

vent?" Cyndi Salito asked.

Jason raised his hand. "OK, we went over the readings from both hoppers already. No sign of any kind of energy surge at all. No zap ray."

"At least nothing we could detect," said Salito.

"We need a regolith sample, just like McConnell told us." Newellen's eyes got a faraway look. "What about storing it in a magnetic bottle? That way the sample wouldn't touch anything."

"Dirt?" said Salito. "You gotta be kidding. Regolith isn't affected by magnetic fields."

"But iron is," said Big Daddy Newellen, "and regolith contains ilmenite, which has iron in it. If we had a high enough B field, we might be able to isolate a sample of regolith. We could put a magnetic bottle on the container. The core-sample javelins penetrate into the dirt, grab a chunk, then launch the container back to the pickup point, leaving their outer shell behind. If we move fast and get a small sample, maybe we can hold a specimen long enough to get it into Sim-Mars, use the isolation lab there."

Jason felt enormous relief at finally hearing something that sounded reasonable. Built over the past three years, the "Sim-Mars" outpost was 50 kilometers away from Columbus Base as a final practice facility for the full dress rehearsal of the planned Mars mission. The self-contained labs at Sim-Mars would be the perfect place to remotely investigate the Farside regolith.

"Sounds like a plan," he said.

In the stuffy closeness of the control room, Jason closed his eyes and tried to

slow his breathing. The javelin probe seemed to take forever to reach the other side of the Moon and shoot back. Right now he wanted to take an hour around the Columbus exercise track, where he often did his best thinking.

Before this, his career on Earth had been easy—designing exotic structures using the new alloys and fibers made possible, through microgravity engineering, playing around with CAD systems and pushing the new material properties to their limits.

He could still hear Margaret's voice as he left Earth, telling him that this job was more than he could handle, that he should just stay home with her. *What more do you want?* she had asked. *We already have more money than we can possibly spend.*

Margaret had never understood him at all.

Jason wet his lips. The manufactured air was so dry here that he frequently suffered from a nagging cough and chapped lips. He swiveled his chair back to the group in the control center, his people. Red and green lights from the panels reflected on the sheen of sweat on their faces. The control center was heavy with the smell of close-packed bodies.

They all waited for the core-sample javelin to do its work. It had already landed, grabbed a minuscule sample in the magnetic bottle, then rocketed the container back toward Sim-Mars, fifty kilometers away from Columbus.

"A real flag-and-footprint mission," Big Daddy had said, waiting for something to do at his controls.

They just had to see if it would remain intact long enough to reach its tar-

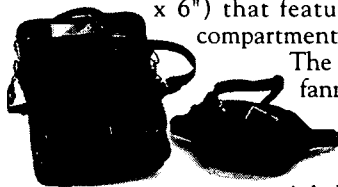
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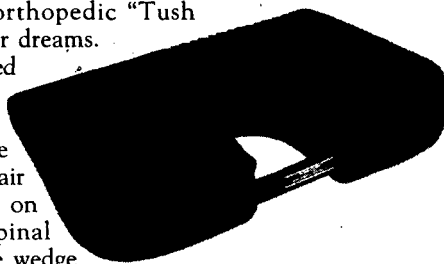
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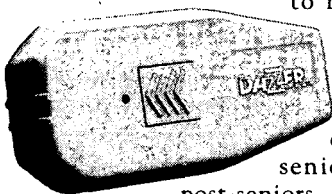
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get, or if the chunk of regolith would eat the container from the inside out.

"Big Daddy, get a teleop rover over to Sim-Mars," Jason said after clearing his throat. "We'll use it to manipulate the sample into the automated lab."

"That'll take one away from Disney World, Jase. Think of the kids crying."

Jason kept forgetting about so many things, so many details. How had Bernard Chu kept track of it all when he had been the base commander? "I think this is a bit more important," he said.

"Big meanie."

Jason ignored the comment. Looking up, he glanced at the digital clocks flashing the time from points on Earth: WASHINGTON DC, JOHNSON SPACE CENTER, STAR CITY, PARIS, TOKYO, HONG KONG. No matter what the various times showed, it hadn't been more than twenty-four hours since the remote hopper had dissolved at Daedalus, two days since the alien construction had been discovered . . . since three of his people had died.

"Heads up," Newellen said. "Sample's coming in." He grinned. "And it's intact."

Cyndi Salito called up another image in the crowded holotank. It showed a dim, cramped room filled with lab equipment that looked too clean, too new. She brought up the lights. "Sim-Mars is on line," she said. "Remote ops."

Newellen hunched over the virtual controls, driving the teleoperated rover vehicle. Reaching the expected impact point, the rover's camera swiveled back and forth, its stereo chip scanning for the

incoming javelin package.

The telero-bot waited, ready to hurry to the javelin and remove the shielded sample as soon as it landed. Back at Sim-Mars, another 3-D receiver also kept watch for the projectile.

Jason wet his lips again. He would have to request some lip balm in the next shipment from Earth.

A splash of dust appeared at the corner of the viewing cube, and the telero-bot's camera lurched over to fix the position. Since the Moon had no atmosphere like Earth, incoming projectiles did not streak across the sky.

"Got it," Newellen said. He worked the virtual controls in front of him, as if he himself were in the driver's seat, rolling across the lunar terrain to fetch the package.

He followed the long furrow in the regolith until he came upon the heavily shielded canister surrounded by ejecta. Using robotic manipulator arms, he reached into the impact site.

"Bingo!" Big Daddy held up the specimen with the rover's arms. Three-D high-definition television gave viewers back at Columbus the sense that they were actually present.

"Off to Sim-Mars," Jason said.

As the telepresent rover approached the isolated training habitat, a quad-armed robot detached itself from the expedition module of Sim-Mars and rolled out to receive the sample. Specially designed by Hitachi-Spudis for conducting detailed geological surveys, the quad-armed robot extracted and deposited its shielded core of regolith into a delivery station, then rolled back toward Sim-Mars.

Newellen peeled off with the telepre-

sent rover, roaring away from the lab. "I'm going to Disney World!" he shouted.

"Cyndi," Jason said, "let him get twenty clicks away from Sim-Mars, then give control back to the kids." He looked at Newellen, grinning. "The other kids, I mean."

A razor sharp shadow extended in front of the quad-armed robot as it returned to the Sim-Mars bay. Fine dust covered the robot as ejecta from the rover's tires fell back to the surface.

The robot rolled around to the service-module entrance and worked the controls to gain access. Through high-definition eyes, they viewed the entry room as it passed through the double doors. Newellen switched over to teleoperating the quad-armed robot just as it finished its preprogrammed sample-recovery procedure.

"We're recording all this, right?" Jason asked.

"Yes," Salito answered. "Agency Mission Control is probably piping it through the newsnets, too."

"Would you guys be quiet?" Newellen said. "I'm trying to concentrate here."

Fifty kilometers away at Moonbase Columbus, Newellen worked with the quad-armed robot. Gingerly lifting the canister recovered from the Daedalus hot zone, the robot placed it inside a thick lead vault. After the vault was sealed, the robot turned to the center of the room, powered down and stood dormant as it waited for further orders.

"Ready for external decontamination," Newellen said.

"I'm running it," Salito called from the back of the control room.

At the center of the Sim-Mars isolation chamber, a meter-thick tube ran from floor to ceiling. In vacuum, low-inductance capacitors made no sound as they charged to thirty million volts. An instant later, a milligram ring of xenon in the tube boiled into a plasma and accelerated to the ceiling. When the plasma ring impacted the high-Z plate on the roof, megajoules of x-rays sprayed through the entire lab room, sterilizing any organism that might have been on the outside of the sample container.

A minute passed. Satisfied that nothing could have survived outside the lead-shielded vault, Newellen powered up the telepresent robot again. Only the sample in the lead-lined chamber remained untouched.

Its own circuits heavily shielded against cosmic-ray bursts and hard solar radiation, the quad-armed robot approached the sample. "Time to open our package," Newellen said.

Jason swallowed a nervous lump in his throat. Daedalus crater seemed a long distance away, but Sim-Mars was right in their back yard. What if they were about to open Pandora's Box?

Lon Newellen shook his head. Sweat dripped from his forehead, soaking his dark hair. *Damn!* Manipulating the waldoes took getting used to, but he had never been this clumsy before.

"Want me to take over, Big Daddy?" Salito asked.

"Shut up."

Newellen flexed his telepresent waldoes and tried to "touch" the contained sample again. The term "Butterfingers" popped into his mind for the

fifth time.

"You sure Director McConnell is watching all this?" he asked.

"Yes I am." Her own voice responded in two seconds.

"I won't make any mistakes then."

Newellen pushed his hand forward and tried to use the fields to pinch the largest chunk of rock in the sample, but it slipped from his grasp again. *Double damn!* Beside it, the opened outer shell of the sample container lay in two pieces.

He ran a sweaty hand across his forehead again, then squinted at the rock. The thing seemed to be growing smaller. And how could it possibly be slippery? The metal walls of the javelin's sample container also seemed to be melting.

"Hey, the temperature's rising inside the vault," Salito said. "A lot more than I can account for by the x-ray burst."

Newellen grunted. "Just let me get my hands on this sucker." He had already completed a third of the standard Extraterrestrial Examination Procedure. So far, except for this problem holding onto the rock, nothing seemed out of the ordinary.

He dropped the rock a third time. Too many people were crowding around him.

Cyndi Salito leaned into the high-definition hologram, blurring its edges. "Say, what did you spill on the sample?"

"Nothing." Newellen debated unscrewing Cyndi's head from her body, but Jason might get upset.

"No, really. Take a look." Cyndi dodged Newellen's elbow and stuck a

finger into the hologram. "Here. It looks like some kind of goo."

"Goo? Move your head, dammit!" Newellen couldn't see with all the people in the way. "Well I'll be dipped. There is something on that rock. Let me play that back, get a closer look." He pulled back from the waldoes and punched up the recorder. The holotank blinked, then showed in reverse-motion Newellen's analysis effort. In backwards time, the goo disappeared and the rock grew larger again.

Newellen stopped the playback. The surface of the sample foamed and seethed. "I think we've brought back something very nasty."

#### CHAPTER 5

##### *Local Mission Control: Washington, DC*

Major General Pritchard looked fascinated and horrified at the same time. Celeste McConnell glanced at him, then back to the main window displaying the remote analysis of the Daedalus sample. They had expected to detect some kind of anomaly on the regolith—thermo-shocked granules, a change in the crystalline structure, perhaps even traces of exotic chemical residue. But nothing like this.

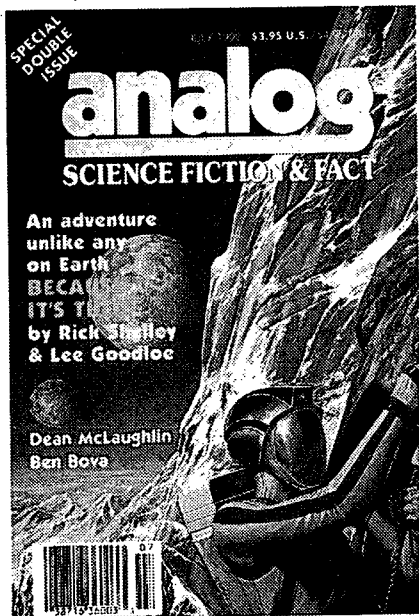
On a separate image, the Columbus control center buzzed with activity. "Are you sure it's contained?" they could hear Dvorak say as he looked at the image of the goo-covered sample.

On Earth, General Pritchard muttered to Celeste. "Of course it's contained. Nothing outside could have survived that sterilization dose, and the sample is behind four-inch lead shielding."

"But what if the contamination can

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break out?" Celeste said.

She turned to Albert Fukumitsu; all of his techs were staring at the moonbase transmissions. Even the Japanese guards at the doorway had turned to watch. "Albert, are we still on? I want to transmit something."

Fukumitsu tossed long hair out of his eyes and indicated one of the techs as Celeste stepped into the transmission zone. "You're on," he said.

"Jason?" She paused long enough for him to look up. With the transmission lag she tried to plan two seconds ahead of his reactions.

Dvorak turned toward her. "Ms. Director, I don't have a clue what's going on, so please don't ask just yet." His voice was sharp and tired.

"I just want you to consider some drastic actions, in case this turns out for the worst. I want all of your people to be prepared to evacuate Columbus if it becomes necessary."

Two seconds later—"How are we going to implement something like that? Take us up to L-1?" Dvorak sounded weary, defeated. "The Collins could never hold this many people, and there's no way the supply shuttles have the capacity to pull off a rapid evacuation. We're stuck."

Celeste pulled her lips tight. Dvorak had a point. What good would an emergency evacuation do? He had turned his attention to her now.

"Look, Ms. McConnell, we appreciate your concern, but the people on my base are accustomed to day-to-day threats. Everything's dangerous out here. We're used to dealing with it."

"I hear you Jason," she said. *Have I just been trying to look good for the*

*newsnets?* she wondered. Celeste had never worried about that before—especially now, with no need to impress anyone. As agency director, she reported to no one but herself. Over and over, the newsnets had lambasted her for those sweeping damn-the-consequences types of decisions, even though they almost always proved successful.

"OK, then let's figure out what this thing is and we won't have to worry about it. I've got a hunch I'd like your team to try."

When he nodded, she said, "Whatever's happening there is taking place on a much smaller scale than we can see right now." Celeste drummed her fingers on her chair. "Use higher magnification. I mean *very* high. You might need to try x-ray spectroscopy, but use the TEM first."

Dvorak blinked. "We're still trying to finish the testing protocol. There's a strict sequence of procedures we have to follow—"

"Super high magnification," she said again. "I think I know what this might be. There's a chance you've stumbled onto something we've been investigating down here—"

"Investigating?" Dvorak looked up sharply. She could see the angry boy behind his features. "What do you mean? Is this something the Agency has done? Are you testing something at Daedalus that I don't know about?"

"No, but we're working on some concepts in Antarctica, as part of the projected Mars mission. This might be something similar."

"And just what is that, Director McConnell?" Dvorak said after the two-second light delay.

“Nanotechnology.”

Pritchard straightened. Most of the people in Mission Control didn't seem to know what she meant. Neither did Jason Dvorak.

“Whatever you say,” Dvorak answered. He motioned to Newellen, still running his telepresent analysis. In the main window showing the close-up of the regolith sample, the view spun inward, defocused, then resolved through a different sensor to show the view from a Transmission Electron Microscope.

Suddenly, the crystalline structure of the regolith sample looked like an enormous city during rush hour. Tiny objects bustled across the screen, swarming and chewing, dismantling the rock, building copies of themselves. Little machines like busy microscopic bulldozers, racing their way up and down tiny structures in the regolith.

A murmur swept through Mission Control, half a second before a similar transmitted undertone reached them from the moonbase.

“Is it a virus?” Pritchard asked, moving closer to the screen. “An infestation, like a plague? Microorganisms—”

“No, not a disease,” Celeste said, cutting him off. “They are . . . mechanical. Tiny, tiny machines.”

The microscopic shapes were fuzzy, boxlike, with tiny lumps that could be arms and levers, crystalline cores that must hold some kind of controls. There seemed to be half a dozen different designs, modifications in the number of flagella, the size of the core. Larger sub-stations were scattered throughout the structure, like control centers.

Celeste pulled a chair up and sat. She

rocked forward in her seat and gripped the arms of her chair. “Jason, you need to destroy that sample. Before it gets loose.”

“It's inside a lead-lined vault.” Dvorak looked puzzled.

“Now!” she said. “Lead won't stop them. Once they finish taking apart the regolith sample and the debris from the recovery canister, they'll start dismantling the inside of the shielding wall, atom by atom, to keep reproducing.”

As Dvorak hesitated, General Pritchard stepped into the transmission area, and raised his voice. Good, she saw that Pritchard at least immediately grasped the nature of the threat. “Dvorak, you saw what happened to your hopper and to those three people—and if these things can dissolve an entire spacecraft, they can sure as hell eat through a lead wall.”

Celeste made her voice placating. “Jason, we can't lose Sim-Mars yet. We need to alter our plan of attack. You can get another sample later—once we've sent you some help. Now at least I know what type of expertise you need. And I know exactly where to get it.”

It took longer than the two-second light delay for Dvorak to show his approval. “OK,” Dvorak said. He directed Newellen to flood the interior of the shielded vault with a decontamination burst.

General Pritchard turned to her. “I can see it, but I still don't understand it. How did you recognize this? What are we looking at?”

“Nanotechnology,” she said to him again, but she knew Dvorak and the entire moonbase crew were listening as well. “Tiny self-replicating robots that

can build or take apart just about anything, one molecule at a time. They're assembling that enormous construction at Daedalus."

Her voice felt cold in her throat. "And these aren't anything we developed. Nothing from Earth."

## CHAPTER 6

### *Antarctica—Nanotechnology Isolation Laboratory*

A strong wind whipped snow into the air, obscuring much of the desolate Antarctic landscape. Inside the Nanotech Isolation Lab, Erika Trace blinked, startled, as Parvu brought out caviar and crackers.

"Where did you get this?" she asked. The soft burr of her Southern accent grew more pronounced with surprise.

Jordan Parvu busied himself with tiny cans, plastic-wrapped packages, and vials of powdered seasonings. "Personal effects," he said. "I have been waiting for a chance to use this, to tell you the truth. Now, we have cause for a celebration."

Erika smiled with the success they both shared. Celebrating with salty fish eggs didn't sound terribly exciting, though.

The NIL's nanocore had turned cloudy as the prototype devices assembled and replicated themselves. The nanomachines functioned better than expected. Taylor was smug upon reviewing the data; Compton-Reasor was ecstatic. Just an hour ago, the prototypes had transmitted their first data to the outside.

Parvu and Erika had proven that they could indeed build functional replicat-

ing machines on a submicroscopic scale, machines that could make a simple analysis of their surroundings and communicate back to the macroscale.

Erika watched Parvu open his tin of caviar. "Well, we have been waiting for this a long time." The fish eggs looked black and slimy. "I've never tried this stuff before."

"Then you are in for a treat, Erika. This is the real thing, from the Amur River in Mongolia. Sturgeon eggs, none of those awful perch egg imitations. You will like this." He craned his head toward her. His hair was neat, his eyes bright, his eyebrows too bushy. "With as much as this cost, we cannot afford to have too many more celebrations, so let us enjoy this one."

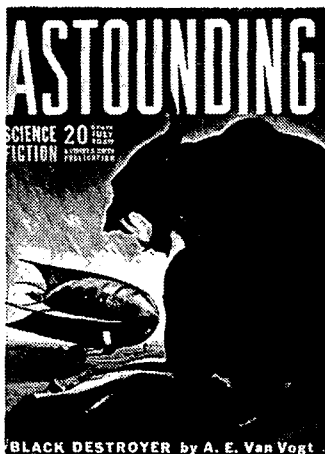
She nodded, keeping quiet. She would do what Parvu asked. He had rescued her from being a perpetual graduate student at MIT, pried her away from Taylor. Caviar was only one of many things she hadn't experienced.

Growing up in Aiken, South Carolina, Erika had struggled with her out of place intelligence in a typical blue-collar family. Her father and her older brother Dick worked at the Savannah River Nuclear supercomplex. Both were beer-drinking, pool-shooting rowdies who listened to songs about big trucks, faithful dogs, and cheatin' women. They scorned Erika's aspirations.

But Erika's mother had made all the difference, planning a better life for her daughter. She had put aside a college fund, collecting enough money so Erika could attend the best schools—and her mother insisted that she excel. With her father's and brother's indifference and

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her mother's pressure, Erika had found herself withdrawing, with no escape but herself.

She had fled to MIT and had worked for Taylor, and might still be there, trying to get her degree. Then she met Parvu, and clung to him. Parvu had seen in her the makings of a good researcher, and she had given him her best work out of gratitude. Parvu seemed embarrassed by it all. He had done his best to talk her out of following him first to Albuquerque, then to Antarctica, but Erika insisted with a savage devotion. She had not felt happier or more worthwhile at any other time in her life.

Occasionally, when she stared out through the insulated windows to see the snow and the rocks, Erika longed to be back in Aiken, with the thick forests, fresh air, and the primeval expanse of Hitchcock Woods. Sometimes she just wanted to listen to the birds again. She remembered spring, with its parade of wisteria, dogwoods, and azaleas filling the air with ever-changing perfume. She had watched from afar as rich people rode horses down the clay paths in front of their mansions.

But then Erika remembered what kind of life she had left behind, and those scant hours of enjoyment in the woods did not make up for the rest.

Here, in their cramped living quarters, with Parvu playing classical music over the sound system, Erika knew she could celebrate much more than just the nanomachine success.

"Jordan," she said, "for you I'll try even salty fish eggs."

Parvu removed two crackers from a plastic package, handing one to her with all the reverence due a communion wa-

fer. He scooped out a bit of the lumpy caviar with a small knife. It glistened like tiny black pearls at the tip of the blade.

He spread the caviar on his cracker, then dipped out another portion for Erika. She took a sniff and imitated his gestures.

"Under ideal conditions," Parvu said, "you accompany the caviar with a slice of boiled egg, sour cream, and chopped white onion. Here, we must make do with their dehydrated equivalents."

Erika sprinkled powder on top of her caviar. She wanted to take only a tiny bite, but she took the cracker whole, chewing quickly to be over the first shock of taste. She was surprised to find the caviar not unpleasant at all, salty and juicy, with only a faint fishy taste. She kept chewing, swallowed, and smiled. A real smile.

Parvu withdrew a metal flask and poured a capful of pale liquid into it. It looked like disinfectant. "Here," he said. "Peppered vodka. It is the perfect thing. Cleanses the palate."

Erika took it and sipped, but the alcohol and the pepper set fire in her mouth, burning away the fishy taste. She felt tears stinging her eyes.

"So?" Parvu said. "We celebrate!"

Just then the communications chime rang through the intercom. Someone was trying to contact them in the conference room within the outer perimeter of the dome.

"Even here we are interrupted!" Parvu sighed.

Erika tagged along behind him, but stayed back, knowing that the communication could as well be from Parvu's

family. They passed through the doors into the outer lab area, and Parvu accepted the call over the big screens.

The image focused, startling Erika as she recognized the caller. They had had little contact with the woman directly, merely transmitting progress reports on schedule. Erika had an uneasy feeling. It was the director of the United Space Agency, Celeste McConnell.

Hovering off to the side, making sure she did not intrude upon Parvu's conversation, Erika listened as McConnell described the Daedalus construction and what had happened there. Erika and Parvu had been so wrapped up in their work with the prototypes that sometimes they ignored the newsnets for days on end.

McConnell showed images of the alien nanotech assemblers, more sophisticated than Parvu's wildest dreams. Erika took a step backward, stunned; she could see Parvu struggling to contain his astonishment. All of a sudden, the major progress they had just made in the NIL seemed utterly trivial. They had been knocked down to the lowest rung of a new ladder.

McConnell paused a long time after her last sentence. Parvu, polite as always, waited for her to continue. Erika knew the director had reached her important point.

McConnell folded her hands. "Dr. Parvu, I need you up on the Moon. You are not only one of the foremost experts in nanotechnology, but you are also the only one with any practical experience. This is not a theoretical problem. I need you to figure out this mystery for us."

Parvu held up his hands as if to ward

off shock. Erika frowned. *Jordan, going away?* What would happen to her? What would happen to their work down here, the prototypes? What if Parvu left and they put—who?—Taylor in charge? McConnell certainly wouldn't let him run the NIL, would she? This couldn't be happening. . . .

Parvu recovered from his shock before McConnell could say anything else. "I am afraid that is most impossible, Madame Director. I am old, and I can be of better assistance if I remain here to give advice, OK?"

"Dr. Parvu, we have no other choice. None of the other nanotech researchers have the hands-on experience you do. They have dealt with theories, nothing more. I must insist." Her voice sounded a bit sharper.

"I'm afraid you do not understand—"

"I'm afraid that *you* don't understand, Dr. Parvu. There's more to this than you leaving your research down in Antarctica. Sixty people on the Moon may lose their lives. And the next fatality may be our entire space program."

Parvu stood silent for a long time. McConnell pulled her lips tight, giving time for him to answer. She folded her arms and waited.

Finally, Parvu opened his mouth. "You do have another choice, to tell you the truth." He reached out and took Erika's wrist, pulling her into view. McConnell's eyes widened.

Erika felt her breath grow short, her face redden.

Parvu continued. "Why not take my colleague, Dr. Erika Trace? I have complete faith in her abilities. She has just as much practical experience as I do,

and a bit more imagination. And she is physically fit."

"I appreciate your suggestion, Dr. Parvu, and no offense to you, Ms. Trace, but frankly . . ." she spread her hands wide, "we need an internationally recognized expert—"

"Erika has published more papers than I in this area, Ms. Director!" Parvu drew himself upright.

Erika couldn't say a thing for a moment. This was worse than she had feared. She did not want to leave the NIL. Was this supposed to be an honor? She supposed so, but right now it sounded like a punishment.

Parvu patted her on the wrist. "We will discuss this further between ourselves, Director. Thank you for the intriguing information about the Moon. We will review it in more detail, OK?" His words picked up speed, as if he knew Erika was trying to gather her arguments. "I will be back in touch shortly." He signed off.

Erika turned on him, balling her fists. "Thanks for making up my mind for me! You all can't just send me away! My place is here. We've got work to do."

Parvu looked at her mildly and indicated the image of the Daedalus construction, which he had frozen in a separate window on the screen. "Don't you believe we can learn more from studying *that* than from any number of years spent here?"

"That's not the point. I don't want to go."

"You are being silly, Erika. With an opportunity like this, you will be the most respected and most envied nanotechnology researcher in the world."

He sounded stern and paternal, not at all like her own father, who would have laughed in disbelief at the thought of his daughter being the only person in the world qualified for an important job. He softened his voice. "Besides, it is time, perhaps, for you to leave the nest."

"Sounds like you're trying to get rid of me!" Even back in Albuquerque he had pestered her with questions of why she had no boyfriend, why she did not go to movies, why she had no social life. Taking it upon himself, Parvu had dragged her off to dinners, forced her to go out to places normally frequented by people her own age—which meant that he himself looked hopelessly out of place.

"Oh, Erika! It is for your own good." Parvu turned away, the matter finished.

Erika did not answer, but instead walked out through the double doors to her own quarters. Their open caviar lay on the table; several crackers had spilled out of the package. She hoped he would feed them to the three lab rats.

The speakers on the sound system began to play another selection from Parvu's CD changer. She recognized it as Mozart's Requiem Mass. Angrily, Erika switched it off. The music seemed too appropriate.

Erika stood alone by the towering rocks and ice sheets of McMurdo Sound. She huddled in a Navy parka, syn-fur gloves, and gel body-warmers, shrouding her face with a scarf. The cold bit into her cheeks. The tall rocks and gray-blue ocean looked like the gates of the Underworld—and she had been cast out.

The ice shelves extending into the water glowed a cold blue from trapped oxygen bubbles. The seas lurched, as if the ocean itself was shivering. Overhead, enormous albatrosses circled like hang gliders with twelve-foot wingspans. On a series of small islands away from the McMurdo installation, jammed penguin rookeries filled the air with an incredible noise, an incredible smell. It seemed numbingly bleak and exotic at the same time.

Years before, she had left the lush forests of South Carolina to travel to the city of Boston, then to Albuquerque and the New Mexico desert. She had thought that Antarctica was the most barren place she could ever see; but now, she found herself on her way to the Moon, with a hasty stop in Star City to cram in astronaut training and certification.

Where would they yank her next? Why couldn't they let her be? Too many times, people had done things "for her own good."

In the distance she heard a jet. Squinting, she could just make out the silhouette of the C-141 Starlifter come to carry her back to civilization—for a few days.

Erika felt stinging tears from wind whipping off the water. As the plane grew near, terror was alive and gnawing inside her—not from fear of space travel, or living on an austere moonbase, or even from the responsibility of being the first person to study alien nanotechnology. Erika felt most afraid to be separated from her mentor for the first time in a decade. ■

TO BE CONTINUED . . .



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# MANUFACTURING MAGIC

*Selective laser sintering  
process converts 3-D  
computer data directly  
into solid objects at Au-  
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Photo credit: DTM Corporation

in the laboratory—using only lasers and common gases—solid rods of carbon and coatings of diamond.

**Solid Freeform Fabrication—SFF**—is today's highest-tech manufacturing process; a way to produce solid objects directly from a computer design, without expensive and hazardous machining or casting. Dr. Joe Beaman of the Mechanical Engineering Department of the University of Texas at Austin (UTA), is a pioneer in this new field. "'Solid freeform fabrication,'" he says, "is the production of freeform solids directly from a computer model, without part-specific human interaction." In other words, this new manufacturing concept goes directly from the designer's idea—as captured in a computer design model—to an actual solid model of the design, with no human work in between. With no factory, no machinists, no assembly-line workers, no inventory, there is just one step between an idea in the designer's mind and an actual object in hand. But this is not science fiction—designers and engineers are realizing the dream right now.

Harry Stubbs, a craggy-faced, soft-spoken technician at AT&T Bell Labs, Indianapolis, was faced with an impossible assignment. "Engineers brought in drawings for a small telephone plug-and-jack assembly," Stubbs said, "and told me they needed parts four times larger in all dimensions, so they could study the design details and make sure the intricate parts fit right. It was a rush job; it had to be accurate and they had

to have their models in two days." The engineers had come to Stubbs because he operated an early model stereolithography machine—STL for short. Working closely with the STL vendor, 3-D Systems of Valencia, California, Stubbs had gained enough experience with his new machine that he was confident he could meet the engineers' demands.

"The basic idea of STL is very simple," he says, "once you understand the principles. You start with a 3-D CAD model and let the STL machine do the rest." The CAD (for "Computer Aided Design") model of a part is designed on a workstation terminal and stored in the computer's software. The computer analyzes the stored data, mathematically "slicing" the solid CAD model into thin layers, a few thousandths of an inch thick. A computer-controlled laser beam then traces out the bottom-most layer of the CAD model in a vat of transparent "photopolymer," a liquid plastic that solidifies when the energy of the laser beam hits it (Figure 1). A platform just below the surface of the liquid plastic supports that first laser-solidified layer of plastic, the initial "slice."

After the first slice solidifies, the platform drops down a specified distance, and the computer directs the laser to solidify another layer on top of the first. Layer after layer this process continues, until the entire solid object has been "grown" from the liquid bath. (Figure 2 shows an actual STL-produced gear.) It is possible to make completely enclosed boxes, spheres or other shapes, but there has to be a hole for releasing

It's early in the next century: you're watching a video shopping channel on your wall-sized high-definition TV set. The huckster is pitching a scale-model classic 1956 Ford Thunderbird, "Powder blue, complete with removable top, roll windows, white sidewall tires, operating headlights and taillights."

The price is right, and you smile. It's perfect for your collection of model antique cars. You press the "ORDER" button on the hand controller and the video screen flashes an acknowledgment: CREDIT ACCOUNT APPROVED. DELIVERY TO YOUR MAKEBOX NOW PROCEEDING. You walk into your utility room, anxious to watch the manufacturing process now beginning inside the cubic-meter-sized box labeled "Mr. Factory."

A control panel voice intones, "Opaque or transparent?"

"Transparent," you say, wanting to view the whole process. The sides of the box slowly fade to clear, and the magical show begins. Suddenly, lights flash and you witness a maelstrom reminiscent of the videos from the deep-Jupiter probes:

*Crackling laser beams of myriad colors repeatedly scanning the internal volume, billowing gases spewing intermittently, multi-colored powders rising and falling in seemingly chaotic rhythms.*

*Out of the swirling kaleidoscope of materials and lights appears first a tiny kernel of white-hot matter, gradually growing into flat planes, then into thickness, into curvature. More gases flow,*

*visible lasers dance, random puffs of powders rise, solidify, fall. An occasional squirt of shiny liquid adds its ingredients to the witches' brew. Tiny nozzles, cables, platforms, vats and pulleys whirl in a miniature version of Milton's Pandemonium, a scaled-down version of the factories of Hell.*

*From the seeming chaos of the high-tech birthing chamber, a shape emerges amidst the swirls. Miniature appurtenances of manufacture withdraw back into Lilliputian chambers, and in the sudden clear quiet a solid object, powder-blue, is left behind.*

*There, on the rotating half-meter diameter dais in perfect splendor, is the twelve-inch long 1956 Thunderbird, its taillights signaling a left turn. You open the door to withdraw your new treasure.*

*Gently, with one finger, you shift the turn signal lever to "OFF."*

This scene is just barely science fiction; the basic technology for a "Make-Box" home manufacturing center, your "Mr. Factory," exists today. And a true revolution, comparable in scope to the old Industrial Revolution of 150 years ago, is beginning right now. In the next century many of our products will be built in such mini-factories, right in our own homes!

For today, commercially available high-tech, computer-controlled manufacturing machines are already "growing" three-dimensional solid objects directly out of vats of liquid plastic and canisters of dry powders in hundreds of shops. And researchers are assembling

# STEREOLITHOGRAPHY APPARATUS

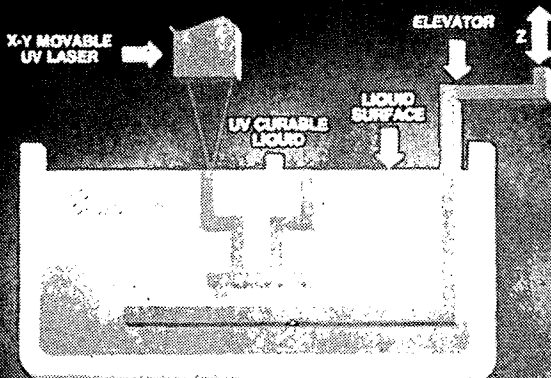


**Figure 1:** Stereolithography (STL) Process: Computer-driven UV laser solidifies liquid photopolymer one "slice" at a time. The "elevator" in the vat lowers the solid model a slight amount, allowing the laser to "grow" the next layer of solid polymer atop the previous layer.

(3-D Systems, Inc.)

the entrapped liquid. "Even a ship in a bottle is no problem for STL," Stubbs says. "For that rush job, I fished out the solid parts from the polymer vat just 18 hours after the process started." He held up the hollow, translucent, two-inch cubelike parts, each over 60 times the volume of the tiny pieces they represented, and pushed them together with a loud *click!* He smiled. "See, they even snap fit together perfectly!"

"There are some proprietary developmental steps in making large, complex shapes by STL. You have to post-cure the polymer and provide internal structure to keep the shape," Stubbs says, "and the plastic models don't have good enough structural strength

for some applications." But the technique is being used by US firms like AT&T, Texas Instruments, Ford Motor Company and many others for one very important reason: STL requires no tooling and no fixturing—just a three-dimensional computer description of the object and an STL machine.

The STL field is heating up with competitors for the revolutionary SFF business. QuadraX Laser Technologies claims that their visible-light laser speeds up the polymerization of liquid plastics, five times as fast as the ultraviolet laser used by 3-D Systems and others. An American-Israeli firm, Cubital, also claims a faster STL method based on a reusable glass-plate system mask



**Figure 2:** What once took weeks now takes hours: An STL-generated solid gear emerges from its photopolymer vat.

(3-D Systems, Inc.)

that exposes one complete "slice" of the 3-D model at a time. Other STL companies are coming on fast with their own novel approaches. But the adventure of the new SFF technology is only just beginning; there's more than one way to "slice" a CAD!

It was a typical afternoon in summertime Austin, Texas; humidity dense enough to swim in, temperature hot enough to fry eggs. But in one red brick building, indistinguishable from all the others in the commercial office complex, in the comfort of an air-conditioned laboratory, a revolution was

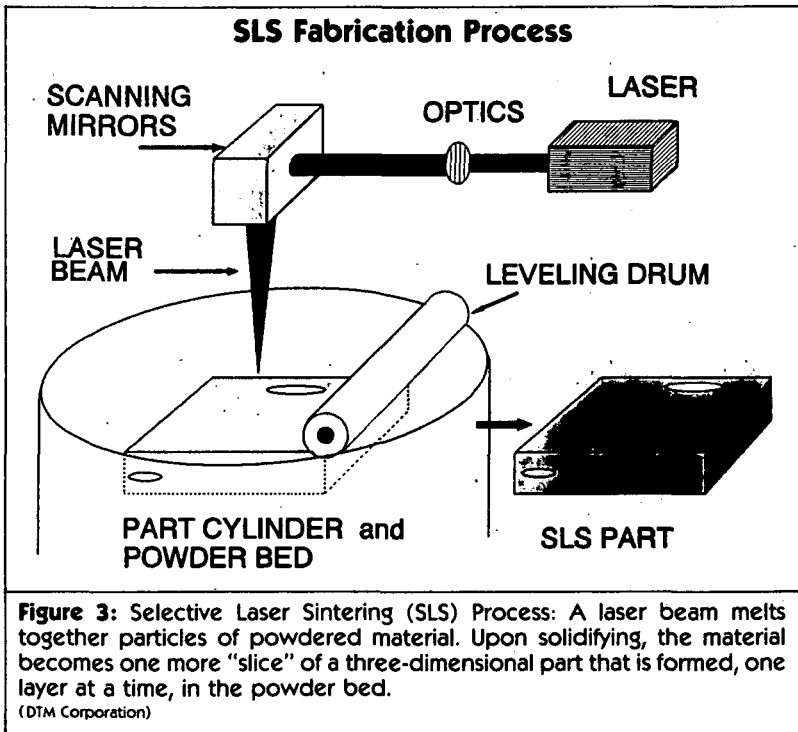
brewing. A group of well-dressed design and manufacturing engineers and corporate executives stood in rapt attention, their eyes fixed nervously on a small window that opened into a large boxy machine about the size of two refrigerators side by side. What they saw was a window into another world, a world that promised serious changes in their lives and in their livelihoods. Relaxing as he leaned against a far wall of the laboratory, a tall long-haired young man in jeans and work shirt, sporting an earring, watched the older men and women with amusement and interest. Dr. Carl Decker, barely thirty years old

and a former graduate student of Dr. Joe Beaman at UTA, smiled as his invention silently began demonstrating another revolutionary change in SFF manufacturing technology.

For there in Dr. Decker's large machine an invisible laser was producing a two-inch-long screw, half an inch in diameter, complete with matching nut, inside a canister of powdered plastic. By a process analogous to STL, a laser transmitted a high-energy beam, but this time instead of targeting a liquid surface, the laser's energy focused onto a thin layer of beige-colored plastic

powder, melting the tiny particles together to form a solid layer (Figure 3). As one layer of powder solidified, a piston under the canister lowered itself imperceptibly. Then a thin roller wiped a virgin layer of powder over the top of the canister, adding a minute amount of new material over the previous layer (Figure 4).

The laser repeated its directed trajectory, its invisible dance, again and again, each time solidifying a new layer of plastic powder onto the layer below. Inside the canister of powder, one infinitesimal layer at a time, a solid plastic



## SLS Powder-Feeding Part-Build Cylinders

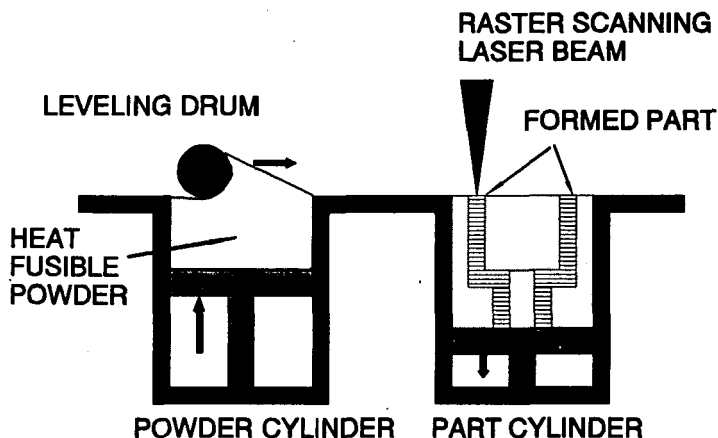


**Figure 4:** Feeding the SLS Process: A leveling drum sweeps heat-fusible powder from the raised Powder Cylinder, left, into the slightly-recessed Part Cylinder, right. The laser beam melts this new layer of powder in a computer-directed pattern. The molten material solidifies on top of the formed part, becoming the next "slice." The process repeats until the final product is completed.

(DTM Corporation)

screw—with its matching nut already threaded in place—was being formed, held in place by the unlasered powder around it. After two hours passed, Dr. Decker, the proud father of a new machine, reached into the canister and retrieved the plastic parts from his invention, holding them up for onlookers to see, the witnesses to the birth of a manufacturing revolution.

Dr. Decker and Dr. Beaman are officers in the DTM Corporation in Austin, Texas (now owned by the large BFGoodrich Company), and they call this latest SFF innovation "Selective Laser Sintering," or SLS. *Sintering* refers to a centuries-old term that origi-

nally meant the melting together of particles of metal to form larger solids, but now applies to plastics as well. That neutral acronym does not adequately describe the passion of the people who invented the process machines and materials, nor convey the apprehension of some of the more rigid minds that have difficulty adjusting to a new paradigm in fabrication.

Decker is a materials scientist who developed SLS for his doctoral dissertation at UTA. "Carl was the quintessential graduate student," says Kent Nutt, DTM's dapper marketing manager, "sort of a '60s kind of guy. Even today," he smiles, "he's not your typical

business executive, even though he has trimmed the long hair a bit." Nutt said Decker and his wife lived in a bus during part of his graduate school days, but his successes with the SLS machines have translated into suburban acreage, a new Corvette, and a sailboat he races on his days off.

But it's not just for Dr. Decker and DTM's employees that SLS has changed lives dramatically. The universal astonishment and anxiety of the on-looking engineers and businesspeople was summed up by a balding man who shook his head, muttering, "It's just not the same. How can that—*computer*—ever be as good, as accurate, as a *machinist*? What are we giving up?" More than one person, however, buttonholed Decker and Nutt to pursue the usefulness of SLS to their own businesses.

"The advantage of SLS over other methods of rapid prototyping," says Nutt, "is that parts are made of actual engineering plastics and other immediately usable materials. And we're a lot faster than the stereolithography machines—usually we can build at one inch per hour, where they may take ten to twenty times as long." Nutt claims that SLS can now fabricate ceramic parts by solidifying polymer-coated ceramic powder, then oven-curing as a secondary process, baking off the plastic and leaving only the ceramic material. DTM has been working with researchers at UTA to achieve SLS with brass, copper, and other metals and metal powder blends. "DTM Corporation," Nutt flatly states, "will provide

to the world marketplace an SLS machine capable of sintering metal materials."

Given the high volume of metal parts production—about 60% of all modeling—producing metal parts directly from a 3-D database promises to revolutionize the newly emerging rapid prototyping industry. Dr. Harris Marcus, a Cullen Trust Professor and director of the Center for Materials Science and Engineering at UTA, was a mentor to Carl Decker and is co-developer of SLS materials with Drs. Decker, Joe Beaman, David Bourell, and Joel Barlow. "Right now, SFF is cost-effective for 'feelies'; that is, you can bring your visualization to reality in just a few minutes. But I don't want to oversell actual manufacturing SFF just now," he cautions, "because the final technology, the one that will produce structural-integrity parts, probably doesn't yet exist. But it will," he adds confidently, "and then we will be able to compete with machine tools for small runs of parts." Dr. Marcus calls his vision of SFF " 'Parts on demand.' You won't have to inventory anything but the raw materials, then just grow whatever you need when you need it—spare parts, small manufacturing runs, anything!" He refers to the promise of SFF as "the ultimate 3-D fax machine. You send the information over the air, and a usable part comes out the other end!"

Other novel SFF methods are quickly coming to the marketplace. A company called Hydronetics reproduces each computer "slice" in a thin plastic sheet, then stacks and laminates them all, cre-

ating a solid piece part. Automated Dynamics Corporation offers an SFF technique called Ballistic Particle Manufacturing, in which tiny particles of molten metal are sprayed from a nozzle, building up the solid piece part in much the same manner as the typical ink-jet printer works. And Drs. Emanuel Sachs and Michael Cima of MIT report using a standard ink-jet printhead from which to fabricate ceramic molds for metal castings. They have successfully sprayed alumina silicates, silicas, and zircon, with various binding agents to hold the particles together in a solid form.

Some SFF devices use lasers and toxic chemicals, limiting their use to a well-ventilated shop or an environmen-

tally safe factory, but one new technique demonstrated by Stratasys, Inc., of Minneapolis, Minnesota, is truly a desktop manufacturing system—one that could be set up on your (large and strong) desk. Complete with its own acronym, FDM (Fused Deposition Modeling), Stratasys's system uses proprietary software, "StrataSlice," that takes standard 3-D CAD data and codes the computer model into layers. A powerful workstation computer drives a heated nozzle head that "plots" the layers of the part (Figure 5). Fed with a spool of plasticlike filament, the nozzle lays down a bead of molten material, much like a hot-glue gun, solidifying one layer at a time until the solid model is complete. Without dangerous materials or fumes, Stratasys's 3-D-Modeler™

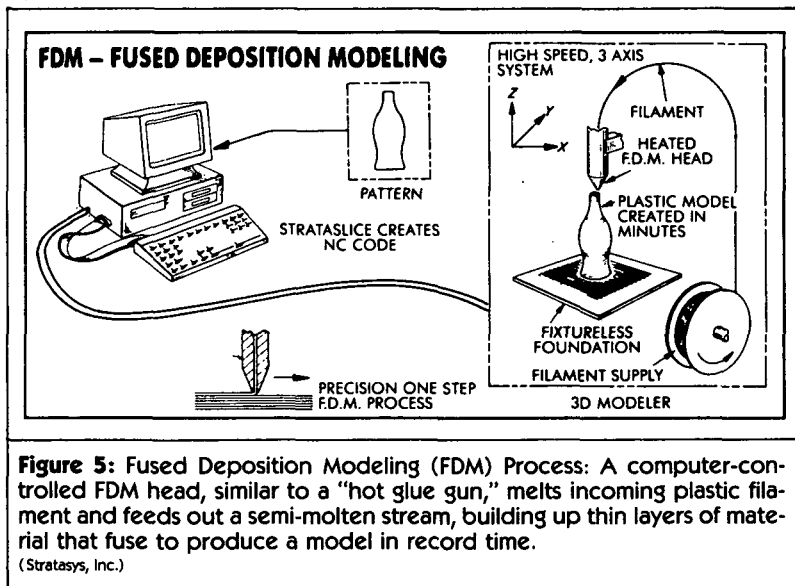




**Figure 6:** The environmentally safe Stratasys 3-D-MODELER is being used in office environments without the worry of exposing users to toxic chemicals, lasers, or liquid polymer baths. The 3-D-MODELER measures 30" x 68" and weighs 250 lbs.

(Stratasys, Inc.)

can be used in an office environment (Figure 6). Speed is another factor in favor of this rapid prototyping system: the plastic model of the head of the Statue of Liberty (in Figure 7) was generated in about an hour.

Solid Freeform Fabrication, though just five years old, is now an established industry. Interest from the industrial community is high, because the prospect of reducing prototype manufacture from days or weeks down to hours or even minutes is staggering in its implications. If US industry can get its products to market that much faster, the economic threat of Asian and European manufacturers may be fended off. It has been not only the quality of foreign im-

ports, but the responsiveness of those manufacturers to American markets that has so challenged—and destroyed some—American firms. Lower labor costs are not the whole story. To date there has been no announcement of SFF machines from Asian manufacturers, but there are reports of sales from Sony and Mitsubishi to internal Japanese markets, and Americans expect the Pacific Rim shoes to fall at any time.

The "cutting edge" of brand-new technologies is usually found in the research laboratories. To bring together the emerging experts in the new field, the pioneers in Austin convened the first annual Solid Freeform Fabrication Symposium in August 1990, covering



**Figure 7:** Liberty Head model made in 57 minutes demonstrates the capabilities of the FDM process. Comparable fabrication by conventional molding methods could take days or weeks.

(Stratasys, Inc.)

the very latest in application and theoretical aspects of SFF. In addition to reports on the immediate engineering uses of existing commercial equipment, experts from US universities and industry discussed and debated the future of SFF.

First, the consensus of the attendees focused on the elemental technical aspect of SFF technology: the computer and its software. Computer technology is absolutely essential to all known or proposed SFF techniques, both to design the 3-D CAD database and then to tell the fabrication machine what to do with the data. In all of the SFF techno-

logies envisioned, software has to capture the designer's three-dimensional model, then properly "slice" it in preparation for an SFF machine to deposit its layers. Of the dozens of CAD systems already available to designers today, not all are compatible with each other or with the proprietary "slicing" programs that SFF machines now use. An industry standard is required so that all users can interchange data. The United States has a vital interest here: whichever nation establishes the standards of SFF machines will have an enormous head start over the international competition. And for the time being at least,

the United States still leads the world in computer workstation hardware and in the software that is the "mind" of the electronic "brain."

Second, Drs. Beaman, Marcus and others stressed that laser beams are the only known ways to achieve the concentrations of energy needed to polymerize or sinter materials. Scientists and engineers are attempting to address the parameters of laser manufacturing—beam spot size, velocity and angle of the beam, as well as the optical and thermal properties of liquid photopolymers and sinterable materials. From these studies will emerge the optimal processes of a mature technology leading to SFF for mass production, giving us Dr. Marcus's "parts on demand."

The most exciting future prospects in SFF came from the reports of graduate students and researchers who presented papers dealing with growing solid objects directly from gas. One speaker told how he had zapped a laser beam through a flow of acetylene gas, growing tiny solid carbon rods in seconds. Although the physical mechanism is very complex to calculate and to implement, basically the laser or other high-energy beam heats up the substrate material until "chemical vapor deposition"—CVD—occurs, where elements condense out of the gas into a solid form. CVD is a well-established technique in the micro-electronics industry, but the goal here is to make, in Dr. Marcus's words, "Any 3-D object we want, not just the flat layers they make in the computer chip industry." So far the Texas

experimenters have successfully deposited at least 25 basic elements with lasers. Even layers of diamond can now be coated, and the researchers look forward to building useful structures from diamond, which is merely one form of carbon.

Gas-phase SFF, as it is called academically, is only in its embryonic stage, with manufacturing capabilities still some years away. For example, the Texans have yet to be able to control their beam focus to grow general shapes, although they hope to someday build complete predesigned small objects out of gas. As a practical limitation, for example, the flowing gas, unlike its powder and liquid cousins, cannot structurally support a top-heavy growing shape, so that elaborate computer software and micro-robotic handling will have to control the growth of any gas-phase SFF objects, to keep them properly aligned and supported during the deposition cycles.

The prospect of manufacturing actual parts out of atmospheric or industrial gases is viewed with skepticism by some observers, but the researchers are quick to defend their experiments and their ultimate goals. "This is not alchemy and it is not cold fusion," one speaker said when questioned about growing diamonds out of gas. "This works, and it works repeatably. Gas-phase SFF is an established technology."

Invited to speculate on the future uses of gaseous SFF, Dr. Marcus predicts the building of specialized materials to order, even microscopic machines of

any design. How might one do this? "With a fine enough laser beam," he said, carefully weighing the import of his words, "there is only one limit to the miniature size we can achieve with gas-phase SFF: the size of the individual atom."

In only five years ultra-tech Solid Freeform Fabrication has exploded from the minds of engineers and scientists into a wide spectrum of practical model-making machines now available off the shelf. Already responsible for a whole new industry—rapid prototyping of engineering and industrial design models—SFF shows promise of eventually making the next leap: the direct

manufacture of final, usable products from computer-aided designs, enormously simplifying production and distribution.

Whatever direction SFF development takes, it is likely by early in the New Millennium that the unbelievable example of the made-at-home T-Bird model will be hopelessly outdated. We may be receiving computer data telling our "MakeBoxes" to construct our clothing, our books, even our food, medicines, or replacement organs. There is literally no telling what miracles we will be able to accomplish, what incredible manufacturing processes we will witness, right in our own homes.

"Mr. Factory," anyone? ■

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#### ABOUT THE AUTHOR

Dr. Arlan Keith Andrews, Sr., is presently a White House Fellow for the American Society of Mechanical Engineers (ASME), as a consultant in the fields of technology transfer and advanced manufacturing, including nanotechnology. In 1991 he was an ASME Fellow for the Technology Administration of the US Department of Commerce in the area of international industrial competitiveness.

A fiction contributor to *Analog* for

the past ten years, and a member of the Science Fiction and Fantasy Writers of America (SFWA), Arlan writes a column, "Technol Errata," for *Science Fiction Review*. He is a Registered Professional Engineer who spent 25 years with Bell Labs on a variety of military projects and consumer products, earning five patents. (This article states the author's personal views only and does not represent the opinion or policy of any contractor or government agency.)

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# Jay Kay Klein's **biolog**

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● Phoenician trading ships probably visited Cornwall, in search of the copper and tin that made this area a center of mining and metallurgy almost up to the present. Cornwall born and bred, Brian C. Coad followed ancestral tradition, securing a B.Sc. in Metallurgy. Raised without plumbing or electricity, and living a subsistence existence on a large feudal estate that hadn't changed materially since the twelfth century, Brian had a great childhood. The best part was roaming an ancient forest covering almost 20 square miles. Next best was the Library Van which came every fortnight from the nearest small town a dozen miles away.

H. G. Wells was preferred reading, and with a taste for science fiction, he contrived to get an education largely on his own, the way most writers do. In addition, he planned to train as an engineer at London University, that red-brick stronghold of the practical arts, so he could support himself while following in Wells's footsteps as a writer. Three years of military service in Venice nearly wrecked his ability to do any work at all, but he recovered well enough to join a series of small companies that were swallowed up one after another by bigger competitors. Hands-on engineering resulted in a score of patents, but recognized as an educated man with imagination rather than just a trained technician, he was given the responsibility of doing things beyond ordinary job descriptions: market surveys in Europe and Japan, coordinator of planning, liaison with patent counsel.

Now living in San Francisco, Brian reached America by answering a newspaper ad for metallurgists. He has been

working mostly on aircraft materials, and lately on applications for precious metals such as gold. A grandfather had been in the United States as a mule-pack gold panner, like many Cornish miners. In Cornwall most people had never been to London, but they'd traveled to Australia, Africa, and America. For Brian, the States felt more like Cornwall than any place in England, with a sense of freedom, independence, and self-sufficiency.

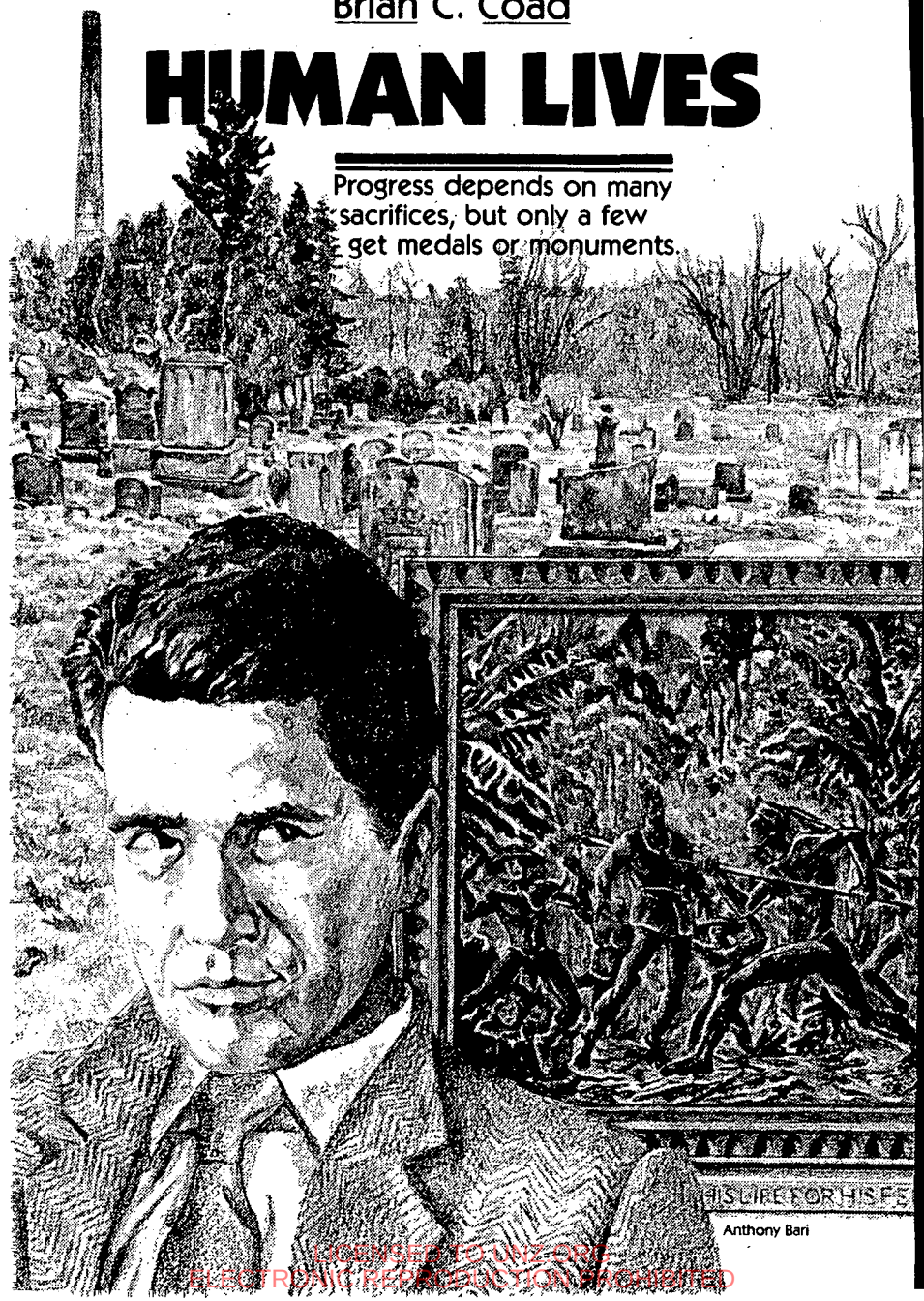
Interested in nearly everything as befits an educated man, Brian is appalled by the vast numbers of people, including most of those in the public eye, who know very little about anything. It's upsetting to find that year after year, "prestigious" literary awards fail to include any science fiction stories. His first story appeared in the February 1974 *Analog*. To his way of thinking, SF is more important than most writing. Here is the power to envision and mold the future. SF can inspire and motivate young people, and has been an increasing factor in guiding young minds. With the application of the scientific method, over time every human problem can be solved. It's dangerous to have a majority of people without any interest in reality, who lack an understanding of science, and are bereft of a sense of futurity. Science fiction can be the bridge between the scientific community and the people who might otherwise continue to go around as if nothing much exciting has happened since the twelfth century, aside from the development of household appliances. Brian believes people are malleable and that science fiction can create a better world by helping forge better people. ■



Brian C. Coad

# HUMAN LIVES

Progress depends on many  
sacrifices, but only a few  
get medals or monuments.



HIS LIFE FOR HIS FEE

Anthony Bari

FORGET TO UNDO  
ELECTRONIC REPRODUCTION PROHIBITED

G.B.I.'s Executive Committee recently appointed Dr. Frannie Smithers president of Frazer Carbon and Graphite Division, thereby demonstrating more wisdom and enlightenment than I'd expect of them. Frannie's the first woman in corporate history to be promoted to high office. Given the trend of the times, the advancement of one lady or another was certain to come, sooner or later. But when the Six Hard Men chose Ms. Smithers for the honor, they had to gloss over the reputation she'd earned for herself as a malcontent—"disgruntled employee" was the phrase of the day—early in her career. It's much to their credit that they didn't let past history sway their judgment.

I've tried several times to write up that old Frannie Smithers incident. Like most of my narratives, it had to do with a patent. It fitted neatly within the terms of reference I normally set for myself. Somehow my scribbles always bog down into a history of Frazer Division, which is relevant, but not the main story. If I keep the historical stuff under control (and that's hard to do—it's exciting) I end up sermonizing, stridently preaching conclusions which I'd do better to let readers sort out for themselves.

Bottom line, I guess, I want everybody to understand Frannie's altruism, and to see that she deserves at least as much acclaim, in her modest way, as the division's inherited hero, Henry Frazer, Jr. Now her promotion's put her on a par with that company martyr, perhaps I don't have to be so evangelical about her. Perhaps I can lay out the story simply, just as it happened.

Henry Jr., and the history will still have to be a part of it, though. I can't

avoid that.

Frannie had been with Frazer Div. perhaps a couple of years when I received in the mail a patent disclosure with her signature on it. I'd had no previous business contact with her, but dimly remembered meeting her at one or other of our corporate technical cross-fertilization conferences. If I remembered right, she was a typical young lady scientist—a slender little person, middle twenties, heavy glasses. She had boyishly trimmed straw-colored hair that would have been more interesting left long and cascading, and a pert little nose pointed permanently upwards, as commonly happens with short people. It delighted me to hear from her, not so much for the business, though I was in a slack period and the disclosure looked patentable, but for the excuse it might give me to visit Frazer Div.

Frazer Div. is located in delightful rustic country near the small town of St. Anne's Wood, in southwest Pennsylvania, amidst hunting territory totally devoid of industrial squalor. For upwards of four generations now, Frazer has employed more than half the working population of St. Anne's Wood. A huge smokestack, once claimed to be the tallest man-made structure in the state, marks the factory. Luckily, the sulfurous black clouds that once belched from its summit (and belch no more since environmentalization) were never able to pollute the fresh country air flowing past it. The plant's black activities have never managed to darken the emerald luster of the forests around it.

The setting alone makes a vacation of

business trips to Frazer Div., but there's an additional bonus. When G.B.I. acquired the previously independent company twenty odd years ago, we inherited, along with the things we paid for, a fine old hunting lodge. The lodge is hidden on an unspoiled estate of several square miles, where great elk wander free along the shores of a wide stream silver with plump trout. True, the elk are imported, the trout refurbished from hatcheries from time to time, but birds chant an endless welcome to executives such as myself, over from corporate. We find the place much more convenient than a motel.

Unhappily, my visits are rare, and difficult to justify. The carbon and graphite industry, which supplies gadgets to transfer electric current from static to moving conductors, is more of an art than a science. Most innovations are maintained within the Division as trade secrets. There's precious little call for a patent attorney. Patent disclosures are so rare that when I received Frannie's, I made a mistake. I called Sam Burgeon, ostensibly to tell him I liked her concept, in reality to see if his patent policy had changed.

Sam was then president of Frazer Div., Frannie's predecessor by two or three. He'd come up through technical channels from research and development. My optimistic fantasy was that he'd decided Frazer ought to get in line with other G.B.I. divisions and, like them, patent anything that came up. Thus I might find myself called upon to labor for countless mellow days at the lodge with no difficult justifications to be made.

Sam soon disillusioned me. He ig-

nored my probing questions, showed interest only in the communication I'd received from Frannie. "Dr. Smithers sent you a patent disclosure? I never heard of it. What's it about?"

I summarized the disclosure for him, new methods and apparatus for blending graphite and carbon powders with pitches and tars, described collectively as binders. The invention had environmental overtones, claiming, among other advantages, its use would protect workers from contact with carcinogens present in tars and pitches. However, the primary advantages would be economic, and those were the ones I relayed to Sam, the ones in which he'd be most interested. Experience has made me aware that in these days of OSHA supervision, it can be indiscreet to say much about those other issues.

Sam's response was calm enough in tone, but there was underlying anger. "That stuff's never crossed my desk. D'you think Frannie has it in mind to take over my job?"

I didn't know about that—thought she was just doing hers. Maybe I should come over there, help him sort it out.

"No need. She's wasted too much of your time already. Why don't you just send me the disclosure. I'll deal with Ms. Smithers."

"Should I keep a copy just in case you decide to file?"

"No. You know our policy. We'd never patent a thing like this. We couldn't enforce it—it'd be handing new technology over to the competition for nothing. Just send the whole package back here."

Thus he denied me my trip to St. Anne's. There'd be no elk for me, no

trout, no birds. Sam was a damn disappointing fellow. I could forgive him for thwarting my hopes, that was nothing new, but I hated to see him frustrate a young inventor. I even dared a mild protest. Frannie's concept was original, any other division would love it. Didn't she deserve—?

He was unswayed. "We've always gone the trade secrets route, Wally. No reason to change now."

That was the end of it. We said polite goodbyes.

I had Ms. Lee, my secretary, address an envelope. By nightfall, Sam's instruction had been obeyed. However, I did keep a copy of the disclosure.

A few days later, Ms. Smithers was on the line, squawking shrilly in my ear. "Why on earth did you tell Sam about my work? You had no right to do that. Lawyers are supposed to keep everything confidential."

"Sam pays the bills. He had to know."

"That's not true. I've read the corporate manual. Inventions are between the inventor and the patent attorney. Management doesn't come into it."

She was misinterpreting the manual, but I didn't think legalistic arguments would be appropriate. I said: "Sorry, Frannie. I did the best I could for you."

"It's not for me. It's for all the people around the country handling carcinogens—"

"You must understand, I'm just a messenger boy, I don't make the decisions—" I tried hard, and wanted, to be nice to her. The carcinogen aspects of the case, though, had little impact on me. G.B.I. exists to make money, and saving lives is incidental. That, at least,

was the philosophy of the time.

"I don't believe you! You have more power than that. Take note, I do not plan to let this rest. I'm going to do something about it!"

Before I could formulate a response, she'd hung up.

I looked at the telephone for a minute or so before I cradled it. Poor Frannie! Poor me, for that matter. Both of us frustrated and helpless. Then I turned back to other work, thinking that was the last I'd hear of that business.

But it turned out otherwise. In the spring of the year following, Sam Burgeon's voice, flat, disciplined, came on my line again. "You remember that thing from Frannie Smithers? The one we elected not to patent?"

Yes. I remembered.

"She's gone public with it. Laid the whole story out in print, under her name."

"Which story? That we wouldn't patent her invention?"

"No, not that. I wouldn't have minded that. The technical details. An article in *Chemical Future*. With nothing left out, and no authorization whatsoever from management!"

I'd heard of *Chemical Future*, a not particularly prestigious magazine that claimed to cater to professionals, and survived mostly on advertisements. It was not the kind of publication that would enhance the reputation of a young Ph.D. But Ms. Smithers's poor judgment was a minor matter. Under G.B.I.'s standard contract with technical employees, any unauthorized publication of her work could place her in considerable legal jeopardy.

I asked Sam if the information released could damage Frazer Division.

"It certainly could. It's a free gift to the competition."

"I guess I'd better come over to St. Anne's Wood, and see if I can help."

"I guess you'd better. As soon as you can."

It was then three in the afternoon. I stopped by the library before I left the corporate tower, but they didn't subscribe to *Chemical Future*. *Nature* and *Chemical Abstracts* were more in their line. I went home, packed a quick bag, and was just able to catch an evening flight from Hartford to Pittsburgh, where a rental car awaited me. It was close to a two-hour drive, along not the best of roads, but I was there around midnight, breathing deep of the cool spring air that, with its load of pollen, would probably have me sneezing by morning.

Late though I'd arrived at the lodge, I was up at dawn, taking a walk by the river before breakfast. The air was crisp and cool, not yet sufficiently pollinated to trigger my allergies. Peep frogs shrilled their morning hymns, fish jumped exuberantly for the first flies of the day, dew damped my shoes, a pheasant screeched out of my way. It would have been pleasant to spend the whole day wandering idly through the woods, but there was another St. Anne's Wood custom of mine I had it in mind to enjoy—a brief meditation before the shrine of Henry Frazer, Jr., hero—before the day's work began. I allowed myself a half hour of bucolic self-indulgence, returned to the lodge, breakfasted on venison steak and a pi-

geon egg omelet, and still managed to be in the Frazer Div. lobby by 7:30.

Everything fell neatly into place for me. The lobby was open, a few early employees were sauntering in, but the receptionist—the same plump country girl I remembered from previous visits—could not yet locate Sam Burgeon. "Won't arrive till eight or so, Mr. Mason. Would you care to take a seat? I'll let you know when he's in." Exactly as I'd planned it.

Frazer Div.'s main entrance lobby is lofty and spacious, its walls paneled with light grey marble designed to offset the black image of the plant's black carbon products. There's something of a hospital atmosphere about it. If it wasn't for the Henry Frazer, Jr. memorial frieze decorating one wall, it would be too antiseptically cold.

Henry's memorial is my shrine, my altar of meditation, after the lodge and the woods, my greatest Frazer Div. joy. It consists of a huge three-dimensional picture, ten by fifteen feet, in cast and patinaed bronze. Henry, a young man in his prime, fitted out in Dr. Livingstone style tropical kit, stands dominating the picture, but is about to fall, as a giant and near naked wild man of the jungle thrusts a terrible spear into his breast. Other naked wild men revolve around in a grotesque dance. A second white man is half hidden in the jungle which comprises the background of the scene.

I drew up a chair, focused my eyes and my thoughts on Henry Jr., his life and times, and settled into my meditations.

\* \* \*

Analog Science Fiction & Fact

Now the history.

The Frazer Company, founded by Henry Sr., was already in business in St. Anne's Wood before 1900. At that time it employed four or five men, and manufactured, of all unlikely things, boot polish. Frazer's Blacking comprised of a thick paste of ground charcoal, suspended in a greasy medium smelling of old leather. There are still a couple of cans of it stored in Frazer archives, under my jurisdiction. It was well made. To this day, the goop has neither dried out nor visibly deteriorated, and it retains its characteristic odor.

Henry Sr.'s own father had made a few dollars, start-up capital for the boot polish business, by cutting and selling firewood to his neighbors. Early success fostered ambition in Henry Sr. His boot polish activity, while profitable and building a fair reserve of capital, could serve only the local market, with little prospect of growth. He began looking around for investment opportunities.

St. Anne's Wood itself had little to offer—just cheap land with no promise in the short or long term of any rise in value. He wanted something better for his money than real estate.

Judging by documents in my possession, Henry Sr. was no better than semiliterate. He subscribed to the Sunday edition of the *New York Times*, probably more to enhance his reputation as a local business man, than to read the news. I imagine he'd scan it, a week or so stale when it arrived on the mail coach from Pittsburgh, memorize a few headlines to quote to cronies in the local bar on a Saturday evening, and give it to his wife, who'd cut it into little squares to be used as toilet paper in their outdoor

privy.

A year or two into the new century, there was a special report in the *Times* on the booming electrical industry. Pages torn from that edition survive in the Frazer archives. Frazer marked with a red pencil an article describing graphite used to make brushes and sliding contacts for current transmission in the new industry. He was pretty bright for a country boy. He recognized that the charcoal he used in his boot polish was not too different from the graphite used in the brushes. After some thought, he set out on a journey which was to be a holiday for his wife, and for himself, an intelligence gathering mission to discover what he could about the graphite business.

Henry Jr. was then seven years old, and was left at home in the care of an unmarried aunt.

The tour was productive. Henry Sr. brought back with him to St. Anne's Wood a variety of electrical machines, a young engineer who was expert in electric motors, and a determination to build for himself the biggest fortune ever amassed in his home town, or, for that matter, in the state of Pennsylvania.

Which he did, not, perhaps, in the state, but certainly in St. Anne's Wood.

Twenty years after Frazer entered the graphite business, Henry Jr. had replaced his father as president of the company. By then, the whole world had become electrified. The First World War had come and gone. The great influenza epidemic that followed had removed Henry Sr., along with fifty million others. Frazer Graphite had grown to employ more than three hundred peo-

ple. The technology was simple, the post-war economy boomed, and prosperity was the mark of the times.

Naturally, that didn't last. As electrical technology changed, specifications for graphite components became more exacting. The business of making current collectors became a complex art. Graphite itself is a complex material, at that time unsynthesizable, with wide variation in properties from source to source. Frazer's graphite came from a West Virginia coal mine. It was not the best in the world, but it was good enough, and cheap. Later, as sophistication increased, Frazer, like its competitors, imported better quality stuff from exotic places like Ceylon (now Sri Lanka) and Madagascar.

Competition intensified. Companies seeking monopoly acquired exclusive control over the principle sources of graphite. Frazer Graphite found itself out in the cold, with no reserve of high-grade raw material available to it.

The archives don't tell me exactly how it happened, but Henry Jr. heard a rumor that there was an untapped source of good graphite in a remote corner of the island of Borneo. He determined that he had a duty to the company (his diary, which survives in the archives, is full of high-sounding reflections concerning his duty) to go off and investigate. He and his chief engineer, a man named Dunkley, took a train to New York City, where they fitted themselves out with tropical kit, complete with pith helmets (I have the receipted bills), caught a steamer across the Atlantic, and thence, by P. & O. via India, to Borneo. More specifically, to Sarawak. Henry's younger brother was left at

home to manage the shop, what was left of it. At that time, Frazer Graphite was close to bankruptcy.

Sarawak, nominally part of the British Empire, was an undeveloped territory ruled by a white rajah. The rajah and his kin, who probably saw little civilized company, welcomed Dunkley and Frazer, offering them every courtesy in their power. The black mineral they sought was not unknown to the rajah, who believed some of his eastern subjects used it in their cooking fires.

Thus, with bearers and guides, the rajah's good will, and a rough map, the explorers set out to penetrate the jungle. At first, all went well for them. The heat was oppressive, the rain forest gloomy, the insects almost intolerable, but there were no serious impediments to their passage. No perilous beasts: Tigers, orangutans—both said to be present and fierce—failed to appear. Head-hunting Dyacks seeking fresh skulls were notably absent. Frazer's diary testifies that their journey was by no means easy, but it was no more difficult than they'd expected.

Some hundred miles from the coast and civilization, they came upon the graphite deposits. It took no prolonged survey to prove that the mineral beds were of high quality, enormously sufficient to supply the needs of Frazer Graphite for generations to come. Dunkley's technical report remains in the archives, and indeed this graphite source still serves G.B.I. The distance from the coast was a negative, but labor was plentiful and cheap. More important, there were no serious barriers to movement—no mountain ranges, no unfordable rivers. The future of Frazer

Graphite seemed assured.

His diary reflecting his elation, Henry Jr., with Dunkley and their twenty or so semi-westernized native attendants set out on their return journey.

In a forest clearing not twenty miles from safety, wild jungle Dyacks attacked the Frazer party.

At the first sign of attack, Henry's porters and guides did a vanishing act into the bushes. Henry Jr., his Yankee spirits equal to the occasion, was not about to let a bunch of wild savages push him around. He stood up straight in the dignity of his tropical uniform, removed his pith helmet, and addressed the person he took to be the Dyack's chief. That individual, huge, fierce, an ivory bone like a white moustache in his nose, a complicated scroll of spiral tattoos all over his body, had not been educated in the art of courteous behavior towards strangers. Devoid of any concept of politeness, he raised his enormous tasseled spear, and thrust it violently into Henry's unprepared and upstanding body. The frieze in the division lobby catches that moment and depicts it precisely—the energy and ferocity of the jungle man; the initially cordial expression of Henry Jr. turning to pained disbelief; the other four or five Dyacks around the central characters celebrating without restraint; and Dunkley in the background, watching anxiously.

For some reason, no aggressive hand was laid on Dunkley. Instead, as Henry Jr. fell dying, the jungle people, uttering bloodcurdling screams (of victory, Dunkley presumed) charged off to their jungle lair. They'd not even stayed to decapitate Henry, Jr. Possibly they'd

believed white men were immortal (a concept much promoted by explorers of the time), and had been as surprised as Henry when their leader's spear hit home. Possibly they feared retribution from the rajah. Whatever the truth was, they departed as suddenly as they'd arrived.

Dunkley, distrustful of his good fortune, was able to creep up close to his leader and, holding him, comfort his dying moments. Henry Jr., with a magnificent effort of will, uttered as he died, the immortal words for which he is still remembered: "Be sure to get the graphite home!"

For a considerable time Dunkley huddled there close to his master. Iron-smelling dribbles of blood polluted his uniform. Parrots and monkeys shrieked.

A twig cracked, startling him. But Henry's murderers had not returned. One of their porters had come back, a shamed expression on his face. Presently the rest of the porters sidled back into the clearing. They did not apologize for running away. Dunkley glared at them angrily until they cringed.

That white man's duty completed satisfactorily, Dunkley gently straightened Henry's body. He stood up, recovered the gun he'd been carrying and had never thought of using. He considered—I have this from his notes in the archives—whether he ought to go in vengeful pursuit of the assassins. It took no long argument with himself to convince him that such an enterprise would be unwise, particularly in light of Henry Jr.'s dying instruction. Calling on his engineering skills, he constructed a makeshift bier of lianas and twigs, on which he had the porters place the body

of their master. Slowed by this extra burden, he goaded and guided them the rest of the way to the coast.

The rajah, on being informed of Henry's death, was upset. He promised swift vengeance. Dunkley, if not a courageous man, was at least a good man of business. He negotiated the rajah's expression of sympathy into a very good deal indeed for Frazer Graphite.

They cremated Henry Jr.'s poor speared body. Dunkley brought the ashes back to St. Anne's Wood with him for interment. He also brought an initial quantity of graphite, quite enough to put the company back on its feet.

From there on, with an assured supply of high quality raw material, Frazer Graphite prospered, so much so that they built a new modern building, were able to afford this expensive frieze in the lobby to commemorate their authentic hero, and eventually became rich enough to attract the attention and the acquisitive instincts of G.B.I.

Here ends the history.

To conclude my meditations in the lobby, I read once more the inscription at the bottom of Henry Jr.'s bronze memorial:

HE GAVE HIS LIFE FOR  
HIS FELLOW WORKERS.

I thought of giants past, and present dwarfs, of old-time courage, and modern opportunism, of loyalty, and loss of loyalty. In short, of all the trite and obvious stuff Henry's story is likely to bring to an average mind.

The receptionist put an end to my reveries. Sam Burgeon had arrived, would I go on in to see him.

\* \* \*

Sam must have entered the premises through some private door of his own. Or perhaps he came through the lobby, saw me at my devotions, and did not wish to interrupt. A bustling, energetic man, no jacket, no tie, his pants held up by crimson suspenders, he greeted me in the corridor, and took me not to his office, but to one of their conference rooms.

Without formalities, we got down to business. He gave me a copy of the article Frannie Smithers had written. In style and content, it was much too high grade for the rag in which it was published. I compared it with her original disclosure, my copy of which I'd brought with me.

The technical parts of the article were taken directly from the disclosure, for the most part using the exact same words. Beyond that, there was a difference. Whereas the disclosure merely mentioned in passing that the invention would reduce worker contact with carcinogens in the mix, the article was oriented strongly towards that advantage. There were several paragraphs devoted to a discussion of cancer in the graphite industry, including some statistics I didn't like to see. I hoped the data was old, that Frazer Div. had eradicated such problems. Not that it was particularly my business. Worker safety was something between Sam and OSHA, of no legitimate interest to the patent department.

The legal position was clear enough. Ms. Smithers had undoubtedly violated her employment contract. She could, with justice, be fired, and no Labor Relations Board would try to rescue her.

G.B.I. might even succeed in a personal suit against her, if we could show damages, though such an action would be futile if she had no resources to pay us compensation for her misdeed.

I told Sam my conclusion, and went on to say: "We can still file for a patent, of course. The rule is, we have a year from first publication. Nothing we can do about the publication itself. Once the information's out, it's beyond recall."

Sam said: "I guess we'd better go ahead and file, then. It won't help us much. No way we can track the competition to see if they're infringing. We'd have to have a spy in every plant in the country."

I grinned. Sam's reputation at corporate was that he had just that. "We'll need Ms. Smithers's cooperation for the write-up. I take it you don't intend to fire her?"

"Hell, no! Frannie's a good kid. Useful member of the team. Besides, she's third generation with Frazer. Her dad worked here. So did her granddad." He flipped his crimson suspenders, and looked at me with an expression I can only call furtive. "Should I get Frannie to come over? Leave the two of you to get on with it?"

"I guess so." I had an uncomfortable feeling there was something he wasn't telling me.

Frannie flounced in five minutes later. She wore a blue denim skirt that flared as she moved, conveying a sense of high energy and independence. Her pert nose pointed upwards, just as I'd remembered it.

Sam made an introduction, defined our business, took his leave.

I extracted from my brief case a virgin yellow pad, legal size. Frannie said: "I told you I was going to do something if you wouldn't let me have my patent."

"You're still blaming me for that, huh? Like I told you, I'm only the messenger boy. I don't make decisions." The words came out harsher than I intended. In principle, I'm liberal in thought and character, but as a long-time corporate man, I'd be lying if I said I hadn't found this young lady's willful insubordination distressing.

"Well, Mr. Messenger Boy, shall we get to it?"

We discussed the invention, an activity with which I was much more comfortable than I was with the inventor.

By a little after eleven, we were done. I told Frannie I'd have the formal write-up complete and on its way to her for her final approval in about a week. She inspected me—coldly, I thought—and said: "I don't believe you're quite such a cruel man as you pretend to be."

I didn't believe there was a trace of cruelty in me. I asked her sharply what that accusation was supposed to mean.

"Nothing, really. I saw you this morning in the lobby, mooning over the deeds of the great Henry Junior. I think, deep down, you're rather sentimental."

"Whatever kind of person I am, it's not relevant to our business. We've done all we can for the moment. If you'll excuse me, I'll get out of here and catch the 2:30 flight back to Hartford."

"Before you go, there's something I'd like to show you. Can you spare me an hour or so?"

Probably not, I thought. With the

two-hour drive to Pittsburgh, a little time for lunch on the way, there wasn't much time to spare. On the other hand, if my flight looked to be unattainable, there'd possibly be reason to stay another night at the lodge. I said: "All right. But just an hour—no more."

Frannie led me out through the lobby, where I bobbed my head to Henry Jr., in passing. To the parking lot. She insisted that we take her little MG to wherever it was we were going. I left my briefcase in my rental car. Her tiny vehicle was cramped, uncomfortable, and noisy, but the clean air whistling around my ears was pleasant enough. She wouldn't say where she was taking me. I wondered if she had some kind of revenge in mind. Maybe she planned to cast me out among savage beasts in the wilderness, or some such thing.

She took me to the St. Anne's Wood Cemetery, a parklike expanse of open land on a knoll above the little town. Rhododendrons and azaleas freshly in bloom decorated its fringes, while several huge oak trees had been allowed to survive scattered among the white gravestones, their vernal leaves rustling protectively over the dead. We entered the graveyard through a white wicket gate that barred passage to cars. Franny's skirt flapped gracefully in the breeze. I still had no idea what she had in mind. During the drive to the cemetery, she'd not answered my probing questions, had, indeed, remained silent most of the way.

I developed a sniffle, the pollen at last getting to me.

The pathways among the graves were covered with sparkling white spar

stones that crunched under our feet. Gravestones near the gate were ancient, weathered. Probably the whole history of St. Anne's Wood was laid out here, ready to be read. I wished I had time to read it. And thought, young Frannie's got your measure, you really are a sentimental fellow.

Frannie hurried me on past the oak trees to a corner distant from the gate. This was evidently a resting place for poorer citizens. The stone memorials were less elaborate, many of them little more than inscribed granite pillows rising in disciplined ranks above the flat, mown grass. There was a scent of hay in the air.

Frannie left the path. She guided me on the grass among the headstones. I noted she took care to walk near the backs of the stones, avoided trampling on actual graves.

She stopped. "Here are the Smithers," she said. "This is my father."

I peered at the marker she indicated. It was of a dirtier, more friable stone than most in the cemetery. Not an expensive monument.

"Note that he died young," she said. "Forty-one. He died of pitch-induced cancer."

I made out the worn lettering. "JOHN SMITHERS II. 1918-1959." Nothing else.

"And this is my grandfather."

Next to John II, "JOHN SMITHERS. 1898-1943."

I began to get a glimmer of Frannie's reason for bringing me here. "He worked for Frazer, too? Another victim of cancer?"

"I'm afraid so." Frannie gestured, her arm encompassing half the cemetery. "There are a great many people

here who worked for Frazer and never saw fifty."

"But this is terrible. I had no idea—"

"Few people have. Frazer Carbon and Graphite doesn't put up a frieze in the lobby to commemorate ordinary workers who quit early. But they gave their lives for the company just as surely as Henry Frazer, Junior!" She spat out the word "Junior," putting more emotion into it than I'm used to hearing in a year.

Her vehemence shocked me. I could come by no words to utter that fitted the situation. I blew my nose violently to mask my agitation.

Frannie seemed satisfied with that reaction. In silence, she led me back to her car. The spring sunlight of midday streamed down on us. A distant cuckoo uttered its muffled, mournful cry.

As I reached down for the string to open the little car door, I managed to ask, without looking at Frannie: "Is it still so bad?"

She gazed out over the steering wheel, her nose reaching towards the sun. "Oh, no. Of course not. OSHA wouldn't let us get away with it. Besides, we now know a lot more. It was more ignorance than any callous attitude of the company, that killed my Pa and Grandpa." She started the car. "We're doing much better lately." She put the car in gear. We began to move.

"We're still not perfect. But before I'm through with Frazer, we will be!"

I have little doubt, now that the corporate masters have appointed Frannie president of Frazer, that she'll achieve that objective. At Frazer Div., henceforth, perfection'll be the norm!

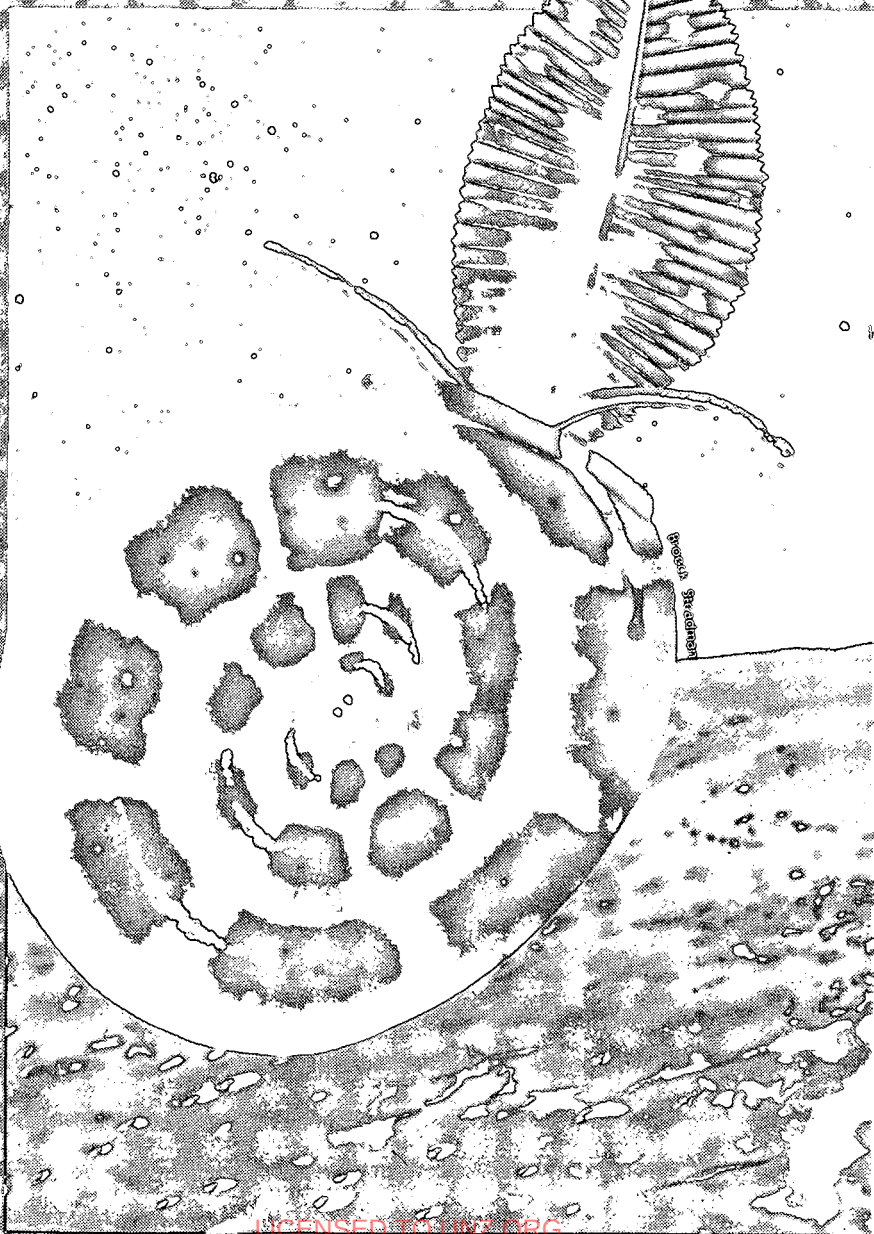
This I dedicate to all those millions, more than have died in wars, who, over the last three hundred or so years, have willingly or unwillingly given their lives to create the industrial civilization which now sustains us. I salute the drunken English, whose penn'orths of gin provided the capital that started it. I salute the women and children who labored on to their deaths in dark satanic mills. I salute the miners who coughed up their lungs from phthisis and silicosis, or who died from rock falls or methane explosions. I salute the researchers and innovators who blew themselves up, or were electrocuted, or who poisoned themselves, or who, from Wilbur Wright to the *Challenger* crew, left Earth behind, flew high, and crashed. I salute the Smithers and their like, who died uncelebrated, and Henry Frazer and his kind, whose celebrity lives on.

Not every day do we think of these people. We owe our present prosperous lives to their sacrifices. Think of them now. And forgive me for preaching. ■

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●Beware lest you lose the substance by grasping at the shadow.

Æsop



Grey Rollins

# INVITATION TO ECSTASY

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What if First Contact is a wrong number?

*Sixteen thousand years is a long time to spend alone.*

*When the instinct to reproduce became nearly intolerable, the creature extruded the membranous organ that served as both ear and mouth through the fist-sized aperture in its stony shell, and listened intently for the signal of one of its own kind. For twelve years it listened, finally catching the faint, seductive whisper that was an invitation to ecstasy.*

*No coy games were played. There was never a question of denial. It was simply a matter of logistics. At first the creature was concerned that there would be no way to rendezvous, but, fortunately, there was a star which would not be too difficult for either of them to reach. It held the added attraction of being comparatively nearby.*

*No extensive plans were made; simply an invitation and an acceptance. With a sense of anticipation the creature began the tedious process of changing course.*

*It would be almost a century before it was within range of its prospective mate, so to conserve energy it tucked itself back into hibernation.*

*And waited. . . .*

Clark Deitz rubbed absently at his upper lip with a fingertip as he stared out one of the two small, double-paned windows at the enormous parabolic radio antenna of the Lunar Far Side Observational Facility, generally called by its acronym, LUFASOF. As director, he had to make a decision as to whether ongoing research should be interrupted.

Behind him, a woman entered the room, quietly coming to stand behind

his shoulder. "You are not happy," she said. "I can always tell these things."

"Was it the screams of anguish or the moans of despair?"

She smiled. "No, Clark, it was nothing so dramatic. Much more quieter, in fact."

He looked back over his shoulder at her. "Tell me, so I'll know how to suffer more quietly next time."

"You have a particular way of sighing. You did this. Also, you are pushing your lip. This way I know that you are to make a decision that you are not like."

"Do not like," he corrected absently.

"A decision that you do not like," she amended.

"Dusya, I have to decide whether to do something about this message," he said, gesturing at the computer's virtual screen. "Either way, I'll be in hot water."

Dusya Litasova, the staff representative from the United Russian Democratic Republic, bent slightly at the waist in order to see the letters more clearly. "So. There is an anomalous radio source in Volans. You are presented the opportunity to set the antenna to listen to this. That would upset our friend Smitters, who has come all the way from Earth to search for hydrogen isocyanide. He is only one, but he is near, which gives him a loud voice. This you must balance against the more numerous but further away voices of those on Earth. By virtue of numbers, they can equal the wrath of Smitters, who is closer. Am I correct?"

"Yes."

"I would say the choice is clear."

"Really?"

"Volans is fish constellation. This tells you what to do."

"And what's that?"

"Go fishing, my friend."

*Food meant energy. The nearer it got to the star, the greater the density of food; not yet great enough. The creature made to fold its cupped membrane back in after tasting the still tenuous, but welcome, broth boiling off of the star ahead.*

*Almost as an afterthought, it sent off another query, hoping to get a reply from its prospective mate, who might already be orbiting the star ahead. Dim memories of rapture were stirring now, and it was having trouble resisting the temptation to scream out its impending arrival. To do so would take too much energy . . . better to wait until it was closer to the largest of the three stars ahead, so that it could more nearly balance energy expenditures with the taking in of nourishment.*

It had been a long, bad day. Clark Deitz was glad to get back to his quarters.

Unlike the more refined tunnels in the cities Nearside, his tunnel had rough, exposed rock walls. He preferred it that way. He liked to reach out and touch the bare ribs of Luna. It gave him a steady point of reference among all the high-tech manifestations and mathematical abstractions.

As a student at MIT, he had sworn mighty oaths that he would endure any hardship, up to and including living in a tent, if it would give him a chance to probe the heavens with one of the big

telescopes. The inevitable mid-life course changes had arrived, one after another, and he had ended up on the administrative side of things, not altogether unwillingly. The old ambition to be near the biggest telescopes remained, however. Only, now it was radio telescopes—the result of an affair with a quiet brunette who had been an electrical engineering major.

The tunnel was quiet. Only a faint susurration from the ventilation duct could be heard, and that only if he concentrated. The silence was blessed and golden after the abuse his ears had endured during the day.

As predicted, Smitters had been beside himself at having his density mapping interrupted. Irrascible by nature, he was nearly intolerable when he had a legitimate grievance. From the invective he had heaped on Deitz's head, one would have thought that hydrogen isocyanide was the single most important compound in the Universe.

That had been at ten-thirty. By five o'clock, after over six hours of futile listening for the mysterious radio source in Volans, Deitz had turned the antenna back over to Smitters.

That had almost been worse than taking it away from him. That Smitters had lost six hours to a wild goose chase was something he did not like in the least. If it had turned out to be sufficiently interesting, he might even have shown grudging interest, but the lack of results exacerbated his ire at losing half of his daily slot on the antenna and he was not to be placated.

That had been one trade-off that Deitz had not foreseen in his youthful ambition—great telescopes came equipped

with prominent scientists, and the scientists often came equipped with explosive tempers. Sometimes it was enough to make him question whether he had chosen his vocation wisely.

*As the creature approached the primary star's southern pole the entire planetary system seemed to be laid out for its inspection. Dimly, it was aware of assorted small, quiet bodies orbiting the primary star, but it was most interested in the three stars.*

*The central star—by far the strongest and most massive—was clearly the best source of food. The second most massive body was much smaller and only radiated in the lower frequencies; clearly not a star after all, although it had not missed by much.*

*It was the third, smallest star, situated between the other two, that started the creature thinking. It radiated strongly in frequencies up as high as the creature could hear. Intuitively, the creature knew that it was far too cold to radiate with so much energy.*

*After considering this carefully, the creature came to the conclusion that it must investigate the matter further. There was something it was supposed to do when it found such a star, but it was unable to remember exactly what.*

Deitz sat staring glumly at the message on the screen. Another signal had been received, this time from near Dorado. The signal had already ceased, for which he was reluctantly grateful. The idea of trying to take any more of Smiters's time away from him was not something he relished.

He felt certain that he would be pres-

sured to track the signal. LUFASOF, at seven hundred meters, dwarfed even the Arecibo dish, although the VLA and others of its class had larger apertures. Its size, combined with its location on the far side of Luna, which blocked out the extravagantly wasteful radio emissions of Earth, put him in a unique position to study the signals . . . if he could have the antenna aimed at the right place at the right time. Fortunately, tuning the racks of receivers was handled by computer. He could listen to 1,048,576 channels simultaneously and tune those rather broadly, if need be. Should the computer receive something that it recognized as a signal, it could immediately switch all of the available channels to that one frequency; paralleled to cancel out residual noise in the equipment.

His curiosity was beginning to nag at him now that a second signal had been received. The fact that it was coming from a different direction was intriguing. Was it related to the earlier one in Volans, or was this one of separate origin? The message he had received from Earth indicated that it had a similar profile to the first one, albeit shorter in duration.

Within an hour after the first signal had arrived, scattered reports had begun to come in, the most detailed being one from an Australian amateur radio astronomer who lived east of Adelaide. He had had the good fortune to be tuned to the right portion of the band to catch the burst.

It did not follow the accepted profile of any known natural phenomenon. No fewer than a dozen hypotheses had been advanced through computer network

special interest groups, ranging from accusations of a hoax to a new class of ultra-slow pulsar. The second signal had utterly destroyed some of the hypotheses, but had in turn given rise to new ones to take their places. Clearly what was needed was more data, but that was in short supply.

Deitz sat back and weighed his options. It would be possible to aim the LUFASOF antenna towards the southern sky in hopes of receiving further signals. Smitters could be allotted half of the available channels, leaving the other 524,288 to be tuned to other frequencies. It would involve a loss of sensitivity for Smitters, as he was currently using all 1,048,576. It was a foregone conclusion that he would not give up any of his channels willingly.

It would also depend on whether Smitters had already mapped that portion of the sky. If he had, then he would surely resist the idea of wasting time going over it again when so much remained to be done. That, at least, would be easy enough to check. The LUFASOF central computer would have records of the aiming of the antenna during Smitters's observational periods.

Smitters would not be happy, but the compromise might work if it was presented to him properly. That left Deitz's path well defined. First, he would have to decide whether to aim towards one of the previous signals or to try to project an orbit if, as one theory had it, this was a free-ranging black hole. Then he would have to consult the computer records to see if Smitters had already mapped that area.

That left the worst task for last . . . presenting the idea to Smitters.

\* \* \*

*The creature felt a persistent itchy curiosity as to the nature of the smallest star. In hopes of finding out more about the enigmatic body, the creature adjusted its trajectory slightly. The new course would take it looping past at close range. This seemed safe enough; the very fact that the star was so cold meant that the creature need not fear being burned. The radiations of the primary star, however, would also be stronger. It would not cause problems as long as the creature did not stay too close for too long.*

*The inability to remember what it was to do when it saw such a star was maddening. Was it possible that it was imagining things? Had it spent too much time alone between the stars, its sanity silently slipping away, unnoticed? A frightening thought, indeed.*

*Still, it was possible that in the half-million years of its existence much had been forgotten. That left a way out—one that did not feel so threatening as doubting its very sanity. And yet. . . .*

*Descending into a quagmire of self-doubt, the creature sent off one confused query as to the whereabouts of its mate before lapsing back into a self-absorbed study.*

*Was it just forgetting, or was it going insane?*

Jans Smitters was dangerously quiet. He sat across from Clark Deitz in the latter's office, each arm draped with mathematical precision along the sides of the chair. His voice, when he spoke, was ominously controlled and even. His words were as deliberately chosen as gifts, each selected to have maximum

meaning; leaving no alternate interpretations.

"Am I to expect any further interruptions of my work, Mister Deitz?"

"Jans, as you well know, this is a transient phenomenon. It is difficult to predict when and where the signal may come from."

Smitters's eyes narrowed. "You did not answer my question," he observed.

"The very fact that the signal *is* transient means that we must study it when we can. Since it is not as predictable as something like a pulsar, then we must avail ourselves of the opportunity to study it when the chance presents itself. Since it came, for all intents and purposes, out of nowhere, and we don't have a good theory to account for it, then it could just as easily vanish at any time. If we lose this chance we may never get another."

"And yet, you have disturbed my studies twice and produced no results. The mysterious signal, be it pulsar, black hole, or little green men, seems not to want to cooperate. Are you certain that this is not just a case of mistaken identity? Will this turn out to be another instance of jumping the gun? Is this another case of Martian canals, soon to be swept under the rug in order to protect reputations? I, myself, find these questions disturbing. It would seem to me that you, also, should consider them carefully. In the meantime, I am being constantly interrupted in my work. This makes it difficult to do what I came here to do."

Trying his best to placate without sounding patronizing, Deitz said, "I understand your concern. However, I'd like to point out that we did not discover

the signal and are only trying to verify something that someone else reported. Surely, there is no danger to reputations involved. If the signal is a hoax, or if it is simply something that has been misidentified, then we should be able, by virtue of our superior signal gathering capabilities, to lay the issue to rest quickly."

"But is that a proper use for such a magnificent instrument as this? To debunk every crackpot theory that comes along? It seems to me that the superior signal gathering capabilities of which you speak would be better applied if we were to place them at the service of research, not chasing some will-o'-the-wisp. Let Jodrell Bank do the job; I know Mark Struthers, he likes this kind of thing. We have more important fish to fry, Mister Deitz. Mark my words . . . this will turn out to be a tempest in a teapot. You will look back on this in five years and thank me for not letting you foolishly waste your time searching for this signal that never seems to be where anyone is looking."

Deitz frowned. "But you've seen the data. This doesn't match anything we've ever seen."

Smitters waved one hand in dismissal before placing it carefully back on the arm of the chair. "I have glanced at it. It is nothing."

"How can you say that?"

"Easily. Common sense will tell you a signal that strong would require a large radiating body in order to have sufficient mass, hence energy, to support such radiation. A black hole would have sufficient mass, but it is unlikely that a black hole would indulge in such, shall we say, erratic behavior. I would

also like to point out that the signal appears to be moving. If there were a black hole, then it would set up a bow wave as it moved through the interstellar hydrogen. It would radiate all the way up into X-rays as gas accelerated in the gravitational field. Similar arguments hold for neutron stars and other such bodies. Asteroids, comets, and the like have not enough energy, other than kinetic, to produce a strong signal such as this."

"Science has often been advanced by following the unexpected lead," Deitz pointed out.

"And even more often has made fools of those who were too quick to jump on bandwagons," Smitters countered. "I assure you, there is nothing out there worth studying. Will you let me continue my research in peace?"

Lips thinning as he grew impatient, Deitz said, "That will depend on how matters shape up, Jans. I have many masters to heed."

"Indeed you do, and one of them is the National Science Foundation. As you well know, they are funding my research here. I will be writing them a formal letter of complaint if you persist in such wrong-headed thinking, Mister Deitz."

"I'm sure that they've heard about this signal. It should not come as a surprise to them that we might want to take a look at it."

Smitters smiled mirthlessly. "As I am certain that they are level-headed men and women who have heard these fantastic rumors . . . and discounted them as any rational person should do."

Deitz sighed. The conversation was not going any better than he had hoped.

The fact that Smitters had, so far, kept his infamous temper in check was small consolation. A quietly angry Smitters seemed more dangerous than a loud and abusive one. He certainly did not appear to be interested in any compromises that might allow Deitz to listen for the signal.

Smitters began to say something, but Deitz did not hear it. His eyes were caught by a slight flicker to one side of his desk. Holding up a hand to stop Smitters, he said, "One moment, please, Jans."

He then turned his full attention to the words being projected by his computer. After perhaps fifteen seconds of reading, he grunted and turned back to Smitters, who was waiting with barely concealed impatience.

"It seems that the elusive signal has been found. It's moved again, but that's no surprise. They're saying that it must almost certainly be the same signal in motion rather than three separate signals . . . I guess that I'd have to agree with that."

"Well, of course it's the same signal! Any fool could see that. It's nothing but a communications satellite that's been knocked out of orbit or something of that nature. For God's sake, must we all stop everything we're doing just because some network on Earth lost a satellite?" Smitters demanded, his voice rising suddenly in volume.

Somewhat taken aback by Smitters's sudden shift to vehemence, Deitz said, "I would think that someone would notice if a major communications satellite were knocked out of orbit, Jans. After all—"

"Bah! Those fools have so much

hardware in orbit that they don't have the faintest idea *what* they have. In another fifteen years we'll have an equivalent amount of junk in orbit around Luna and no one will have any peace and quiet!"

"Jans, I—"

"Mister Deitz, if you have any sense at all, you'll send back a polite acknowledgment of their message and ignore those idiots. There are far too many projects lined up for LUFASOF for you to go bumping honest research off the schedule just to waste valuable air-time chasing ghosts!" He stood abruptly. Being from Earth, he misjudged the force of his action and bounded slightly off the floor. His embarrassment at this loss of dignity only added to his anger. "And I'll thank you not to disrupt my research any more, Mister Deitz," he bellowed and stormed out of the room with as much speed as the lower gravity allowed.

Deitz sat absolutely still for almost a minute before even daring to breathe. That Smitters had reverted to his usual form was almost a relief, but that did not make the man any easier to bear.

Taking a deep breath in a futile attempt to calm himself, he then went back to reading the rest of the message on his screen. It gave the coordinates, noting that they were consistent with the first two signals in establishing a track. A map, almost ridiculously tiny as reproduced on his screen, plotted the three points and drew a dotted line to indicate the orbit extrapolated from the available data.

A brief analysis of the signal followed. The content was as mysterious as the first two. The duration was the

shortest yet. Questions abounded.

Of course, if Jans Smitters had his way, no one would spend any further time at LUFASOF trying to answer those questions.

*The point had been reached where food density, though still low, was sufficient to begin feeding in earnest. As the creature approached the central star the food density would continue to increase, but the risk of being burned by the too-intense energy would also increase. A delicate balance would need to be struck between availability of food and proximity to the star.*

*The creature began by unfurling its multipurpose organ. It set the large, circular membrane so as to catch the maximum amount of stellar wind and began feeding—occasionally correcting when the wind and light pressure had pushed it too far out of its chosen orbit.*

*The surface of the membrane absorbed hydrogen and oxygen ions directly, taking them through the circulatory system, into the body where they were brought together as water. Heavier elements were also caught, particularly magnesium and silicon, which it combined with oxygen to produce the hard external shell that protected its delicate internal organs. That magnesium and silicon were comparatively rare in the wind from this particular star did not bother the creature—there were other stars where it could get them easily.*

*The problem of the third star still bothered the creature. It was nearer now in the physical sense, but no nearer to solving the conundrum of how such a small, cold body could radiate so*

brightly. In spite of much effort, it was still unable to remember what it was to do when it discovered such a star.

There was a still smaller, colder body orbiting the small star. It radiated also, but not with the richness of the larger body. Its orbit was somewhat wider than the track the creature had originally set. Seeing the opportunity, the creature adjusted its course to take it between the two bodies in such a manner that their gravitational fields would exactly balance one another.

With the simple pleasure of a surfer catching a demanding wave, the creature used its membrane to tack across the wind into the invisible path that would carry it safely between Scylla and Charybdis.

Aside from the pride of a difficult thing done gracefully, the creature hoped to be able to learn more from this new orbit. It would allow the creature to approach the small star even more closely. Perhaps something could be learned.

Charles Ling was an altogether easier man to deal with. Although he was, at present, only getting a third of the available hours on the LUFASOF antenna, he was far more agreeable to the idea of parting with some of those hours.

"Mister Deitz, I have no problem with diverting some of my time into trying to find this signal. I only ask that you allow me some advance warning if possible. As compensation, however, I would like immediate access to any data that might be generated in these attempts. I may or may not be able to make anything of the signals, but I would like the chance to try."

"Recordings of any data we record will be available for everyone to evaluate," Deitz said. "At this time we are simply trying to confirm the presence and origin of those signals. Evaluating the signals will be something that we will all try our hands at, I imagine."

Ling frowned delicately. "Why is it that our friend Smitters will not donate some of his hours to this attempt?"

Deitz sighed. "I'm afraid he believes that the signals are either faked or some entirely ordinary phenomenon that has not been interpreted properly. He thinks it's a waste of time."

"It is sad that he has so much air-time and cannot see fit to allow even one of those hours to us."

"I know. That makes me even more grateful to you, who have comparatively less to give, for graciously allowing me to interrupt your research."

Ling gave him a wry grin. "It is not necessary to butter me up . . . I am as curious as anyone to find out what these signals truly are."

Deitz sighed. "If only everyone saw it that way."

*With food came the capacity to switch into the higher of its two metabolic states. At last, shudderingly awake, the creature began diverting a large portion of the incoming nourishment to the organs within its body that would generate its mating calls. Closely analogous to the battery-like organs in an electric eel, they comprised nearly 80 percent of the creature's internal tissues.*

*A quirk of the creature's physiology allowed it to reverse its metabolism, at least out in the membrane. Whereas the*

*surface of the membrane had been absorbing elements from the stellar wind and passing them into the circulatory system, it now turned the process around. Magnesium ions, carefully hoarded in a substance analogous to fat, were sent back out into the veins leading into the membrane. The outer surface began to take on a silvery sheen as the metal was deposited. Effectively, the creature plated the surface of the membrane from the inside out, vastly increasing the efficiency of its transmitting and receiving processes. The musculature of the extended membrane had already cupped it into a close approximation of the desired parabolic shape. The membrane's ability to absorb nourishment dropped nearly to zero as the magnesium accumulated, but enough had been stored to last for a while.*

*The last step was to erect the stalk that would serve as the actual transmitter and receiver. It appeared from a slightly puckered area in the center of the membrane, growing quickly until the head felt the strongest reflection of the star's rays. Having calibrated itself in this way to the curvature of the parabola, the creature was now ready to begin the search for its mate.*

Jans Smitters caught Deitz in the corridor.

"Good morning. I hear that you have finally caught the mysterious signal. What did it turn out to be?"

Deitz stopped. "I don't know yet. I'm on my way to the control room to look over the data now. You're welcome to come, if you'd like."

Smitters scowled for a moment, then shrugged. "Very well. If nothing else,

it will soon be time for my slot at the antenna."

As Deitz resumed walking; he could not resist saying, "Ling was kind enough to allow the last hour out of every shift in order that we might try to track the signal."

Smugly, Smitters replied, "Just a communications satellite. Nothing to worry about."

"I don't think so," Deitz replied noncommittally as he turned through the portal leading into the control room.

Dusya glanced up when she heard him come in. "Ah, you are here. Good." Her eyes caught Smitters and narrowed. "And Jans Smitters, as well. How good of you to drop by," she added with only the faintest trace of sarcasm.

Smitters nodded regally, but said nothing. He gave no sign of noticing her animosity.

Deitz stood next to Dusya. "So what have you got?"

"I got nothing. LUFASOF has a good, clear signal, though." She gestured at the display. "Repetitive. Every twelve seconds it goes through a damped oscillation. Not usual looking for anything that I have ever seen."

Deitz studied the graph showing signal strength for a moment. "Just a plain sine wave. The amplitude builds, peaks in the second cycle, then drops over the next nine seconds. Silence, then starts over. Damnedest thing I've ever seen. What's the decay envelope?"

Ling spoke from where he was seated in front of a console nearby. "Not exponential, logarithmic, or linear . . . nothing obvious. I'm trying to fit it to a curve, but I haven't had any success

yet."

Deitz glanced around the room, seeing more people crowded around a young man seated at another console. "What's Tanqueray got?"

Dusya glanced over at the group before answering. "He is linked to Earth. They are using corrected angular data to locate source of signal."

"You mean—"

"Signal is far within Solar System. They are trying to triangulate. Unfortunately, they are having trouble syncing our computer to the ones on Earth in order to determine phasing."

Smitters chuckled smugly. "See? I told you it would turn out to be something ordinary. It's going to be a satellite with a circuit that has become unstable. It's oscillating. Call the communications people on Earth and you'll find that an orbital correction thruster jammed and they've lost a satellite." He stifled a yawn. "And now, if you'll excuse me, I'm going to eat breakfast and gather my notes. Some of us have serious work to do, you know."

Watching Smitters's retreating back, Dusya said, "Do you think I should have said him that orbital track shows it to be inbound from somewhere outside Solar System?"

"Should have told him," Deitz corrected, but his mind was elsewhere.

What was out there?

*No answer. So far, the distinctive warble of the mating call had not been answered. Its mate was probably still on the way in to the comparative warmth near the campfire of the star. Figuratively speaking, there would still be hands to be held to the flames and a*

*great deal of muttering about how cold and lonely it was out away from the fire.*

*Still, the creature kept up the transmissions. There was no way of knowing when the other might open up and hear the words of welcome. It would continue to call out until it exhausted its reserves, at which point it would carefully reabsorb the magnesium and turn its thin, leathery membrane towards the primary star for more nourishment. Over and over it would do this, for as long as it took to make contact.*

*Meanwhile, the creature was drawing ever closer to the small star and its companion body. Subtle course corrections were made, based entirely on the creature's ability to feel the gravitational fields of the onrushing bodies. Incredibly sensitive organs with dense cores like pearls surrounded by layers of soft, yielding nerve tissue, read the microgravity fields with remarkable accuracy.*

*Balancing the need to establish communication with its mate and its curiosity about the small star was becoming increasingly difficult. The urge to mate had a tendency to overwhelm all other concerns. Soon, though, it would be relaxing its orbit—taking itself out to a cooler, safer orbit. One where it could devote its entire attention to mating.*

Charles Ling's mouth was already slightly upturned at the corners, giving him a perpetual faint smile, but there was no doubt that he was also giving a tired smile of satisfaction as he gingerly laid his head back against the top of the seat. "Well, Clark, I think we can safely say that we have a bona fide mystery here."

Dusya, still sitting upright in spite of having been awake for nearly twenty-four hours, said, "And to think that mystery is keepsake."

Deitz frowned slightly as he tried to puzzle out what she had meant to say, but gave it up, rationalizing that he was too tired. If nothing else, her occasional mangling of the English language gave him a fresh perspective on things he took for granted. "Did Tanqueray ever determine the . . ."

Dusya nodded. "Yes. He left the program running. The last time I looked, it said that the orbit is a least bit over forty-one degrees off the plane of the ecliptic. He said that the computer would continue to refine the orbital parameters on the data that came in from the antennas on Earth."

"Then he went off to sleep," Ling observed enviously. "Something I should have done long ago."

Deitz arched his eyebrow. "I don't recall seeing anyone holding a gun to your head. You could have gone to bed any time you wanted."

Ling sighed good-naturedly. "Ah, but sleep is difficult when there are so many unanswered questions. This is a magnificent puzzle. What is this signal? Where is it coming from? Why has it chosen to begin broadcasting now? These things fire my imagination, Clark. Enough so to keep the tiredness at bay—for a time."

Deitz chuckled. "But you still don't know anything. You've stayed up for nothing." He turned to look at Dusya. "You, too."

"Did not," she retorted. "I now know that I don't know anything more than I knew before. That means that I

now know something."

Ling screwed his face up. "What need have I of fabled Oriental inscrutability when we have Dusya to baffle us in this way?"

"Just think of it as wisdom from peasant," she replied serenely.

*The creature did not get bored repeating its unvarying phrase. Like the song of a bird it was announcing its whereabouts to prospective mates and greeting the dawning of a new day. The vast majority of its life was spent in the deep reaches of space, hibernating mostly, as it coasted from star to star. That made the small percentage of time it spent awake even more precious.*

*The creature was one of the few who did not wait for the warming rays of a star met by chance to bring it out of hibernation. It actively sought out stars as it drifted through space. This involved a trade-off. The ability to choose—to actually steer towards a star slightly off of one's original path—afforded the opportunity to mate more often, to mix the gene pool more efficiently, but the time spent awake, listening, waiting, and using the membrane to catch the slightest of pressures to steer towards a star was fraught with peril. There was the threat to sanity, of course, for what creature can stand to be alone with its thoughts for a century or two at a time? There was also the very real chance that it could squander its precious life-sustaining resources out far from any hope of recovery; in effect, to starve to death, trying to catch a long shot.*

*The creature did not think of this as the ubiquitous pressure of evolution*

*forcing the species towards a more reproductively efficient future. It was more immediate.*

*Mating felt good. It was enough to seek it out.*

When Clark Deitz walked into the control room again later that morning he found Jans Smitters lurking over young Tanqueray's shoulder. Deitz could not immediately make out the words, but Smitters's tone sounded bullying.

"Ah, Jans. Good of you to join us this morning!" Deitz said with all the friendliness he could muster.

Smitters pivoted from the waist, still bent, to look back at Deitz. "Is there any reason I should not be here? This is part of my allotted time at the antenna, and yet I find that it has been spirited away by this young man."

Forcing a smile he did not feel, Deitz replied, "Well, to begin with, he didn't spirit it away. . . ."

"So I see. It is being squandered here underneath my nose while there are more important things to do."

". . . and he has been working at this problem with my blessing."

This brought Smitters to his full height. "Indeed? He did not tell me this. So you are interfering with my work yet again. I warned you that I would be writing to the NSF if you persisted in this foolishness."

Ian Tanqueray's eyes crinkled with merriment as he leaned around Smitters's somewhat corpulent form. "Um, Clark? I've got the orbit out to about three or four decimal places that I'll put money on. The computer insists that it has a few digits beyond that, but it doesn't have money to back its predic-

tion. There's also a little more."

"More?" Deitz asked. "What kind of more?"

Tanqueray's eyes glittered mischievously. "The good kind of more."

"Can neither of you keep your minds on serious work?" Smitters demanded. "My God, you're acting like school-boys with a frog in a shoe box!"

"Just call me Galvani," Tanqueray teased.

Deitz laughed in spite of himself and Smitters left abruptly, muttering dire threats under his breath about people who couldn't take their responsibilities seriously.

Tanqueray, still young enough to have a streak of rebelliousness in him, said, "You'd think that he would have learned to take things with a bit of humor by his age."

"Be careful, Ian, you'll be his age one day if you live long enough—something I wouldn't care to place a bet on, if you continue baiting him that way."

Tanqueray snorted. "Pompous ass that he is. Speaking of asses, you'll note that I had to do a considerable amount of leaning to talk to you around his . . . um, rump."

"You're trying so hard to be tactful that you're giving a very distinct impression of what you want to say."

"Good," he said with a wicked smile, "that's exactly what I meant to do."

"Back to the subject at hand. What's this 'more' you mentioned?"

"Well, you know this orbit I've been helping to triangulate?"

"Yes."

Unable to bring himself to draw it out any longer, he said, "Well, you see,

once we had anything like hard numbers, there was this fellow back on Earth with three meters of optical who just couldn't stand not—"

"Dammit, Ian, what did he see?"

A small smile broke over Tanqueray's face. "Computer enhancement shows a disk. Spectral lines indicate magnesium absorption." He paused dramatically. "Clark, there's somebody out there, and it ain't us."

"Oh, dear . . . oh, me." Deitz fumbled for a chair and sat as heavily as Lunar gravity allowed. "Oh, God."

"Estimated eighteen meters diameter," Tanqueray continued. "They aren't sure because the image is pretty fuzzy, but it seems that there's something behind the dish. Probably the satellite body."

Deitz leaned his face into his hands and rubbed his face slowly two or three times as though he could stir up thought that way. Finally, he exhaled noisily and looked up again. "Ian, I feel both young and old at the same time." He narrowed his eyes. "There's no chance that this is one of ours that got away, is there?"

"You mean like Smitters has been claiming? No way. As far as we're concerned, this thing is coming in from outer space."

Deitz nodded to himself. "Plus the fact that anyone who puts up something that big is damn well going to keep track of it. It had to be expensive to build."

"Exactly. There's only one way I can think of to get around that."

"And that is?"

"Supposing that some government put up a big surveillance satellite that misfired on orbital insertion. They

would know that it was missing, but they would not be likely to admit that it was theirs."

"Good point," Deitz acknowledged.

"So far, though, no one will own up to a missing spy satellite. It looks as though we might just have ourselves a genuine piece of E.T. hardware."

Deitz shook his head. "I hope this doesn't turn out to be a bust."

Tanqueray shrugged. "The orbit argues against it being anything of terrestrial origin."

"Hmmm. I wonder what would happen—off the record, mind you—if we were to fire off a few seconds of that same signal right back at the source."

*It wasn't exactly boredom. It was more like self-absorbed concentration on producing the most perfect mating call. An art form in itself. So preoccupied was the creature that when the replying trill came back it almost missed it.*

*It was off axis. Considerably. So much so that the signal was weak and localization was difficult. Quickly the creature angled its membrane so as to spill some of the wind and began to reorient itself towards the signal. In its excitement, the creature inadvertently altered its orbital track. It took several hours of judicious corrections to reestablish the proper trajectory.*

*The trill was gone now, but next time it would be able to catch it more closely.*

It was dark. The total, unrelenting darkness that comes of living encased in meters of stone. And Deitz could not remember why it was that he had awoken.

Until the computer announced again that there was an incoming call.

Groggily, Deitz made feeble pawing motions in the direction of the computer's synthesized voice. "Answer the call. No video. Don't turn on any lights."

"Yes, sir," the computer answered.

"Clark! Get moving!"

"Ian? What—"

"It's talking to us! For God's sake, man, get down here."

"Talking? Who's talking, Ian?"

"The satellite. I sent off another signal and it's . . . oh, never mind, just get down here. Right now!"

"You in the control room?"

"You'd better believe it! Me and everyone else . . . nearly."

"Nearly?" Deitz felt as though his mind was on a slightly mistuned wavelength. He was unable to get his thoughts in order. "What do you mean, nearly?"

"Well, under the circumstances, I didn't think that it was necessary to disturb our dear friend Smitters. After all, he has been under such a *terrible* strain recently, I thought that it might be kinder to let him sleep."

That got through to Deitz, and he grinned in the stygian darkness. "I see. I'll be there in ten minutes." He broke the connection.

"*Lights!*" he bellowed at the computer.

*Nineteen hours after reorienting its antenna, the creature was rewarded with another reply. This time it caught the signal in its entirety. Just as humans are able to stereo-locate with their ears, the creature was able to sway the sensi-*

*tive tip of its receiving appendage back and forth by minute amounts, effectively changing the direction from which it received most efficiently. With excellent accuracy, it homed in on the signal within seconds.*

*Consternation racked the creature. The signal appeared to be coming from the surface of the cold body orbiting the small star. An impossibility! Surely, it had made a mistake in locating the source of the signal.*

*Surely?*

When Deitz arrived in the control room, he found every eye upon him.

"We need you to rubber stamp a few things that we've done, Clark," Tanqueray began. "You see, I've found it necessary to requisition a few things in your absence. Nothing much, really, just a few tens of thousands of pounds worth of equipment that nobody else was using . . . nobody important, anyway."

"So *that's* why you didn't want to wake up Smitters," Deitz observed.

Tanqueray frowned and shook his head slightly as though confused. He looked at Dusya. "Do you know anybody named Smitters?"

A terrible actress; nonetheless she gave it her best. "No, Ian. I don't think I know anybody by that name. Nobody home but just us birds."

Deitz rolled his eyes. "Don't overdo the innocent act, you might hurt yourself."

"We are cold on the trail, Clark," she assured him.

"You mean hot, don't you?"

She waved a hand to dismiss the matter. "No matter. We have *spunik*."

"Whoa, now. Speak English, Dusya."

"We have satellite. It is visitors. We must prepare to receive it."

Deitz glanced at Tanqueray. "Is she saying what I think she's saying?"

Ling called over from another terminal, "Precisely that, friend. Our elusive satellite is heading almost straight towards us."

"Here?"

Ling and Tanqueray nodded simultaneously. "The signal changed not long after it received the second burst," Tanqueray said. "The signal it's sending got a great deal cleaner and increased slightly in frequency. As a matter of fact, the frequency is varying slightly. Whatever they're using for a transmitter is drifting. Either that or the bugger operating it isn't very good. Naturally, it could just be that their equipment has been damaged by a meteor or something."

"Optical observers say they've lost the disk. It has turned towards us and lost the Sun," Ling added.

Mary Dey, who worked with Tanqueray, said, "Clark, we need to decode this signal. Our working hypothesis seems to be that this is a satellite sent by an intelligent race. It's important that we figure out what they're saying as soon as possible."

Tanqueray pointed out, "So far, Mary, we don't really have a great deal to work with. Basically, it's just the same signal over and over again. For all we know, it's saying 'Polly wanna cracker.'"

"You just said that the signal is varying, Ian. What if that's part of the message? Just because we use AM and FM

separately doesn't mean somebody else can't use them together. It would make for a denser packing of information."

Deitz frowned. "I have the feeling that I've walked into the middle of something, here."

"You bet!" Mary said hotly. "Why isn't somebody working on this?"

"Because none of us are linguists?" Tanqueray ventured.

Deitz scowled. "Mary, I understand what you're saying, and I agree, at least in principle, but I'm not aware of any computer programs to decode alien radio signals. Even if there were such a thing, we don't have the software here. We need, as Ian says, a linguist of some sort."

"Of some sort that doesn't exist," Tanqueray shot back. "There is no such thing as a specialist in extraterrestrial languages."

Mary glared at the two of them in turn. "Oh!" she spat. "You're impossible. We've stumbled into the greatest opportunity since—"

Deitz held up a hand to stop her. "Mary, Mary, Mary . . . please! If you have any ideas as to what to do, then do them. I'll back you to the fullest. By all means, call Earth and see what you can find, be it software or human assistance. Find out who's tops in the exobiology field and start trying to track them down. Frankly, I doubt that you will be able to find anyone who can help us, but it's worth a try."

Lips compressed, she replied, "Very well. I'll see what I can do." She left hurriedly.

Tanqueray breathed a sigh of relief. "Thanks. She's been bouncing off the walls, demanding that we do some-

thing, without once giving any rational suggestions as to exactly what. She's a wonderful person, but I don't think she handles the unexpected very well."

"*Harrumph!*" Deitz grunted. "If this goes on much longer, I might just decide to *help* her throw her little tantrum."

*For all practical purposes, the creature was blind with passion. Its curiosity about the nature of the small star was being subjugated by its need to mate. Grimly, it held itself to the task of getting through the gravitational gauntlet ahead. Deftly playing the solar wind and light pressure, it accelerated as it prepared to thread the needle. Only hours remained.*

*Although the answering signal had transmitted in fits and starts at first, it was now continuous, strong, and clear. It had also begun the faint tremulations that indicated its mate's building excitement.*

*But still it seemed to come from the surface.*

Early the next morning, after a futile attempt to catch a few hours rest, Deitz leaned over Dusya's shoulder. "How's it look?"

"It is good-looking, Clark. The variations are increasing, both in amplitude and in frequency." She glanced up into his face. "Still do not know what this means. Mary has had no luck finding anyone who can interpret the signals."

Deitz chuckled. "Indeed. I would be more than a little surprised if we were able to crack their language this quickly. Hell, I had trouble sleeping—I kept trying to guess what they're

saying."

Charles Ling laughed quietly. "I know what you mean. I was too tired to be awake and too awake to sleep." He shook his head sadly. "I might as well have stayed here. My thoughts were here, even though my body was not."

"That is change," Dusya said. "Normally it is your body which is here and your thoughts which are elsewhere."

Deitz laughed gently at Dusya's rejoinder. Her grasp of English was shaky enough that her jokes did not always make sense. He made a point of laughing at the ones he understood as a subtle means of reinforcing her mastery of the language. "What's Smitters doing during all this?"

Ling pursed his lips as though tasting something sour. "He graced us with his presence a few hours ago. Very little was said after I told him that our friend," he gestured out towards space, "had changed course after receiving our signal. Then he left."

"He didn't raise a fuss?" Deitz asked, surprised.

Ling's eyes sparkled. "No. As a matter of fact, Ian performed some of his computer wizardry and announced that Smitters is in the computer, using the statistical analysis routines."

Deitz shrugged. "Probably studying his isocyanide data. At least—"

"I think not," Ling interrupted. "Ian says that he has made copies of every data set pertaining to the incoming signal."

Deitz raised one eyebrow. "You don't say."

"It is interesting, isn't it?"

Dusya asked, "Have you given any

thought to what we will do when the satellite enters Lunar orbit?"

Deitz stood absolutely still for several moments. "Orbit? Did you say orbit?"

"Must do this," Dusya explained to him, as one might explain the obvious to a child, "or all is found."

"I think she means to say 'all is lost,' Clark," Ling put in.

"So you think the satellite is definitely coming here?"

"Here. Yes," Dusya said. "It is visitors. I told you this last night. Perhaps you should get more sleep. You are forget things too easily."

"You can say that again," Deitz muttered.

"Excuse? Oh . . . sorry. I said you are forget things too easily."

"I wasn't asking you to repeat . . . oh, never mind." He walked over and peered out the window at the huge radio dish, even now pulsing invisible communications out into space. "I just wish I knew what we were saying."

*The urge to mate was ascendant. A burning desire to get as close to the origin of that seductive warble as possible. The temptation to throw caution to the wind and—*

*No! Danger ahead! Only unwavering attention to detail would get it through safely.*

*It was a matter of concern and confusion to the creature that the signal seemed to come from the surface. Briefly, it considered the possibility that its mate was in a close, extremely tight, fast orbit, hence not on the surface at all—skimming over it at a low altitude. Such a daredevil orbit went against all instincts. By nature a denzien of deep*

*space, it was properly wary of gravitational fields. Its primary mode of transportation was to ride the light pressure and the tenuous wind of charged particles that came from the stars. This was a reliable and elegant method of travel, but it had its limitations—one of them being that the creature lacked the power to counter very strong forces. By instinct and experience, the creature was afraid of the gravitational well surrounding every large mass in much the same way that humans are born afraid to fall.*

*The emergence of a second signal caught the creature completely by surprise. As near as it could tell, it was every bit as powerfully excited as the first signal.*

*There were two mates waiting!*

Ian Tanqueray bolted forward in his seat, frantically snapping switches. "Bloody hell! What's going on out there?"

All heads snapped towards him. "What's wrong, Ian?" Deitz demanded.

"Some bastard on Earth must be flinging another signal at the satellite! I'm getting a reflection from our Overstar II satellite."

"You mean—"

"Somebody dirtside is doing the same thing we are, but they're pouring on the power. Their signal is so strong that a stray reflection from Overstar is damn near overloading my front end. I had to switch in the limiters in order to get the signal down to something I could work with."

"Jesus," Deitz whispered.

Dusya said, "Too many pots in the

kitchen spoils the broth."

"Cooks," Deitz muttered distractedly. "Dammit, we don't even know who's sending the signal." He thought for a moment. "Somebody figure out who's over the horizon down there while I call up my phone list on the computer. We've got to get this stopped."

*The creature turned its ear towards the newer mate. The signal grew stronger and stronger. When fully aligned, the creature was nearly deafened with the intensity of the return call.*

*This mate was on the surface of the star!*

*Stay away, stay away. . . .*

*But a signal that strong indicated a powerful state of excitement. The depth and power of the thrill! Such expression! Such need!*

*The creature did not recognize that both signals were counterfeit; merely a retransmission of its own signal. In its naivete, it assumed that each of the signals it could hear were expressing the deep, heartfelt need of another of its own kind.*

*Indecision was something that it had never experienced before. In this sense, evolution had failed the creature. Nature had never forced on its species the ability to think quickly. What use is swift thought when action, by necessity, is slow to the point of being glacial?*

*The second signal was more powerful, hence, seemingly, more excited. To this the creature responded on a primitive level far below that of its reasoning mind. Heedless of the danger, the creature was drawn as powerfully to the new mating call as a moth is to flame.*

*It set a spiraling course downwards.*

*There was no denying the lust which was upon it.*

There was a rising hubbub of confusion in the control room at LUFASOF. No one voice carried that much anxiety, but the aggregate of the tension in the room was palpable.

Ling's voice was not loud, but it carried a clear, ringing quality that made it intelligible over the background noise. "The satellite is turning away. It appears to be homing in on the other signal." There was almost a sadness in his voice. "Any luck, Clark?"

"It isn't VLA, and it isn't Jodrell Bank. I've got a call going through to Arecibo right now. If it isn't them, I'm going to . . . ah! Hello! This is Clark Deitz, up at LUFASOF. I'd like to speak to Hal Renfroe, if he's there."

Without needing to be told, everyone in the room fell silent as they listened to Deitz's side of the conversation. It took almost five minutes for Renfroe to get to his end of the line, but once he did, it took only moments to ascertain that Arecibo was indeed the offending installation. Finally, Deitz nodded once and sat back, closing his eyes. "Thanks, Hal, I owe you one." He reached out and tapped the button to break the connection.

Ian grinned at him and nodded approvingly. "You're good at that. Me? I'd have gotten on there and made his life hell. It would have taken an act of God for me to get the time of day out of him. Tact is not my strong suit."

"It's not mine, either, Ian. I just got lucky."

"Luck like yours I could use. Now,

let's see if we can talk to this satellite."

Deitz gestured grandly. "It's all yours, my friend."

*The sudden cessation of the stronger signal caught the creature unprepared. It made no sense. The only thing that would cause a mate to quit sending was if it went back into hibernation—but this signal had been strong. That seemed to indicate that the mate had already fed and built up strength enough not to require further hibernation.*

*In short, there was no reason for its mate to suddenly fall silent. It was tantamount to coitus interruptus. Had it been rejected as a suitor? Swirls of turbulent thought coursed through the creature's mind as it tried to unravel the mystery.*

*Fighting back the confusion that threatened to swallow it, the creature measured its proximity to the surface below and saw that it was being inexorably drawn into the gravity well surrounding the small star.*

*Terrified, the creature began to expel fecal matter, carefully hoarded for just such a contingency. With utmost delicacy and attention to aim, it voided its lower digestive tract, using the mass to accelerate against the grasping tendrils of gravity. A fringe benefit was that this slightly reduced the creature's mass, making it more maneuverable.*

*Against all odds, it made it back to safety. Indeed, it was going to overshoot slightly. Any moment now, it would need to make a slight tilt in its membrane to counter the last vestige . . . but wait, the original mate was still transmitting!*

*Should it try to rendezvous?*

*But the danger. . . .*

*The desire, the longing for fulfillment!*

*It hesitated . . . and was lost.*

Dusya turned to Deitz. "I think we have problem."

Having been leaning over Ling's shoulder, Deitz turned and looked at her. "What kind of problem?"

"I am looking with the computer at the orbital path of the satellite. It changed back towards us after the Are-cibo signal quit, but now the computer is telling me that the satellite must crash."

Deitz straightened and stepped over to the console where she was working. "What makes you say that?"

"So far, we have seen no indication that the craft has any high acceleration available to it. Truly, they may be saving their reaction mass, but I don't think so. It has been using its antenna to maneuver against the solar wind. The acceleration that way is very slight. We have been watching in infrared and other wavelengths. There has been no indication that the craft used any kind of exothermic reaction to increase velocity."

Deitz frowned. "There must be some way that thing can maneuver. Has to be. Nobody would go to the trouble to send a satellite all this way only to let it crash when it got here."

"We did," Ling pointed out. "We crash-landed a great many satellites when we first started exploring Luna and the other planets."

Deitz shook his head. "I still don't believe it. It's just too wasteful."

Dusya shrugged. "If it is to insert

into stable orbit or make a soft landing, it had better do something soon.”

*Too late the creature came to its senses. The original signal was still there, sending faithfully, but there was no possible way that its prospective mate could have made it to the planetary surface alive. If nothing else, the thin membrane, even when coated with magnesium, could not withstand the gravitational stresses of being planet-bound.*

*The creature tried to break off its approach, but the feeble acceleration that the membrane provided was no match for the remorseless pull of Lunar gravity. All it managed was to change slightly the point of impact. It had committed itself irrevocably to the gravitational embrace of the Moon.*

*The knowledge of imminent death had an effect different from what it would have had on a human. Just as a human passes on its legacy through its genes and strives, above all, to protect its progeny, the creature's impulse was to save its personal history. All that it was and all that it had seen, felt, thought, and experienced, was what mattered now. It must spray out its life in the hopes that another would receive the message and learn from its experiences. Perhaps even avoid making the mistakes that killed it.*

*Then, belatedly, wondering, it realized what the emissions from the surface meant. They were the signals of another life form. Clearly, they were able to tolerate the gravity, as preposterous as the notion seemed.*

*Though it had failed in its aim to mate, it could partially redeem itself by*

*greeting the new life form even as it died. With calm resignation, the creature turned its membrane towards the source of the signal and, in a fashion not unlike that of having its life flash before its eyes, it began to recite its autobiography—edited, to remove the unbearably long silences between the stars. Perhaps they could use it as a foundation upon which to build an understanding of the language, should another pass this way.*

*A melancholy feeling of satisfaction stole over the creature—at least it was not insane.*

“The signal's changing!” Tanqueray shouted. “It's modulating differently.” Without being asked, he routed a display of the signal to the main computer buffers from which each console drew its screen contents.

“What do you think it means?” Mary asked.

Deitz studied the graph for a second before saying, “I hope they aren't asking for help, because there isn't a damned thing that we can do.”

“We could hold a fireman's trampoline. . . .” Tanqueray joked nervously.

“Where will it hit?” Deitz asked.

Dusya typed steadily at her keyboard for a minute. “The computer projects impact about 250 kilometers east of here. Slightly to the north.”

“We still might have something to worry about if that thing masses very much. At impact it will have appreciable velocity. With enough mass that could represent a great deal of kinetic energy.”

She frowned. “Judging from the acceleration it can get using its antenna, I

estimate 500 kilograms, or a little over."

Deitz nodded, looking thoughtful. "It still might surprise us and change course at the last instant. Just to be on the safe side, let's close all the pressure doors manually. I'd hate to take any risk that we can avoid. I'm afraid most of you will need to go to your quarters. The life support backup for this room can't handle this many people. Your individual tunnels will be able to sustain you much longer if something should go wrong."

There was some grumbling at this. "You'll be able to monitor the incoming data as effectively from your quarters as you can here. I am going to stay here. One other can stay."

It took several minutes to decide the issue, but eventually Dusya won the final coin toss. "I am glad to be here, Clark."

He flashed her a quick grin. "Me, too. Now, we must get a perfect recording of the incoming signal so we'll have something to study after the satellite hits. It's not likely there'll be enough to study after the impact."

"Is anyone watching for the strike? It would save time to have a good idea where the satellite hits."

"It's too dangerous, Dusya."

"If satellite crushes on landing . . . does not explode . . . we might be able to get enough to analyze alloys that they use."

Deitz considered it, but shook his head. "Not worth the danger. We'll just have to get a good fix on it as it goes down." He snorted to himself. "Paradoxically, if it hits hard and makes a crater it'll be easy to find, but it won't

be worth the trouble of looking because everything will have been vaporized by the impact . . . if it hits softly enough for there to be any identifiable fragments, then it'll be harder to find because there won't be a very large crater."

"Sad to come all this way to end like this," Dusya said.

"I know, but I don't see that there's anything we can do to help that."

*The creature could not see the surface, but it could sense the closeness by the faint low frequency hissings radiated by all celestial bodies. Its field sensing organs were screaming in agony, not having evolved to be subjected to this strong a microfield.*

*Still, the creature transmitted. Ignoring the growing pain from within, it poured forth its life—every joy and every defeat. Oddly, it felt no rancor towards the beings below. It was its own fault that it had blundered too close. Now it must pay the price. Hopefully, they would forgive it for not establishing long-term communications.*

*Ahead was the source of the signal—then flashing beneath and slightly to the right—then behind, unable to track the hurtling creature—mercifully missing its death shriek as the pain became too great to bear.*

*Even before it hit, the creature died. Its internal organs lacked the strength and resilience to withstand even the tiny tidal forces it was experiencing. Externally, its rocky shell and antenna survived until the end. Then they, too, disintegrated.*

The survey team took nearly two days

to find the impact site. There was rejoicing, followed by confusion.

The satellite had landed in the dust that filled the bowl of a small, pre-existing crater. After looking in vain for identifiable metal parts on the surface of the deep pit of dust, one of the crew decided to check the crater rim, just in case.

What he found shocked the scientists gathered in the control room at LUFA-SOF into stunned silence.

Deitz said very carefully, "I'd like you to repeat your last transmission, please."

"Uh, I know what you're thinking, Clark, but I'm not pulling your leg. There is a small jagged outcropping here. It grazed the rim on the way in. Obviously, the antenna stuck way out past the body of the . . . the rest of this thing and part of it was ripped away as it went by."

"And it looks like?" Deitz prompted.

"I swear, I'm telling you the truth, Clark. It looks like a piece of white, untanned leather with a shiny side. Metallic looking. It may be silver, it may be . . . hell, out here nothing would tarnish, so it could even be sodium, for all I know, but it's going to be some kind of metallic coating."

"So it was *alive*?"

"I'm going to bring this piece in for you folks to look over. Then you can each draw your own conclusions, OK?"

"But from what you're saying—"

"Just a second, Clark, Hansen's trying to talk to me on another channel."

Deitz fumed while the man spoke to the other. "God, I hope that thing

wasn't alive."

"Clark?" the survey member said.

"I'm here."

"Hansen says he's found what looks like a fragment of a shell. That's shell as in *seashell*. The concave side is smooth, the convex side is pitted, possibly by micrometeorites. It's thick . . . maybe thick enough to maintain a decent pressure differential if it was intact. We're talking about something like a nautilus or a snail, with the majority of its soft tissues inside a protective shell. Obviously with at least one opening for the antenna."

"That's impossible!" Deitz exploded.

An exasperated sigh came over the radio. "If you want to argue with him, Clark, he's on channel thirty-seven. I'm just telling you what he's telling me. This thing wasn't a satellite in the sense that we know. It was a living being."

"How could a seashell—" Deitz began.

"Hansen says the country rock here is basalt, with an intrusion of something I've never heard of off to the west a ways. He has eyeballed this fragment and tested it with his Portaspec. He says it's forsterite. He says that's the magnesium end member of the olivine family, whatever in hell that's supposed to mean. I don't understand half of what he's telling me. Maybe you should switch over to thirty-seven and talk to him."

"No," Deitz said, defeated, "I just don't want to feel as though I witnessed the death of the first extraterrestrial to visit mankind."

"It's not as though we shot the thing down, you know."

"I know."

"Listen, I'm going to have to get in some equipment if you want me to find out more about this animal. For my two cents worth, we're lucky to have found anything, but anything else we're gonna find will be at the bottom of a hell of a lotta soft, fluffy dust. In a way, that's good, because it would have cushioned the impact. But it's also bad, because this dust is hard as hell to work with. It's up to you, buddy."

Deitz thought about it for a moment before answering. "Stay out there a little longer. Set up the temporary shelters. Let me see if I can scrape up enough money to get the equipment you'll need sent over from Nearside."

Deitz broke the link and sat back in his seat, staring moodily at the ceiling. "Christ. It shouldn't have ended this way."

Tanqueray sounded dejected. "Um, well. At least we have the recording of whatever it was broadcasting."

"Small consolation. I'd rather have the creature. There's no telling how long it will be before we hear from another one. Probably never. The logistics of a being that lives in deep space would keep there from being very many of them."

"Plenty of room," Ling observed thoughtfully.

"It's food I'm thinking about." He stopped and thought, then nodded to himself. "It would almost have to feed near a star."

"Then why was it talking? It had to have taken a fair portion of its metabolic output to send those signals. There would have to be a good reason for expending that much energy."

"Uh . . . damn. I don't know."

"Oh, that's easy," Tanqueray put in.

"Well?" Deitz prompted.

"Sex. If they eat at stars, then it would make sense to mate there, too. That way, the energy expended while mating could be replenished before going back out into space. It would be similar to the way that birds tend to congregate around lakes and things. They could kill two birds with one stone, so to speak."

Deitz nodded slowly. "That makes sense. And stars are easy to find. They advertise their presence by radiating across a broad spectrum . . . including radio bands, which this creature was obviously equipped to handle. Fascinating. Why didn't I think of that?"

Tanqueray gave him a pitying look. "Well, you know, in deference to your old age, I just thought I'd remind you that we younger ones still have hormones."

But Deitz was not listening. "And it was coming towards us because we were transmitting its mating call back to it. Oh, dear God. I did kill it, just as surely as if I had shot it with a gun."

Just at that moment, Smitters entered the room, smiling broadly. "Good evening, ladies and gentlemen."

Taken aback by his civility, Deitz replied, "Good evening, Jans. Under the circumstances, I think that it's safe to say that you can have the antenna back."

Smitters chuckled under his breath. "Not necessary at the moment. I'm awaiting confirmation of receipt of my preliminary manuscript on this most interesting creature that we've been talking to."

"We?" said Deitz without thinking. "You wanted nothing to do with the project."

"Oh, come now. I graciously donated time at the antenna to the study of these broadcasts. Now, I am happy to say, I have a preliminary breakdown of the language units used in the poor creature's broadcasts. I have submitted a preliminary diagram of concept blocks—might as well call them words—and hope to have the honor of being the first person to publish in this fascinating new field. After all, being able to find the divisions between words *is* the first step of learning a new language." He waved airily. "Well, must go, I'm expecting my confirmation any minute now."

With that, he glided back out the portal and away.

"*Graciously!*" Tanqueray spat. "Why, that bastard wouldn't know graciousness if it bit him!"

"Under the circumstances, it does seem to me that he might be termed insufferable," Ling observed.

Deitz took a deep breath. "I am prohibited by my title as director from making scurrilous comments about scientists who may be conducting research here at any given time, but I must say that his version of events doesn't seem

to match what I recall."

Dusya began muttering under her breath; something that seemed to consist of entirely too many consonants.

Deitz raised one eyebrow. "And what does that mean?"

"Smitters is ungrateful, illegitimate child of . . . never mind. Polite lady should not speak in this way."

He sighed. "Well, just for the record, I agree with whatever it was that you just said, even though I didn't understand it."

"Will teach you sometime."

Deitz waved a hand. "Not necessary. I'll let you say it for me. At the moment I have other things to think about, anyway." He sighed. "Like how to tell the world that I've killed the only extraterrestrial we'll ever see."

*Even as he was speaking, in a roughly circular orbit a third of the way to Mars, the mate who had first invited the creature to the Solar System unfurled its membrane and transmitted a query. Surely, the one who had answered its invitation would have arrived by now. It was simply a matter of making their orbits coplanar and matching velocities.*

*It had been such a long time. . . .* ■

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Probability Zero

# **FERMAT'S LEGACY**

Ian Randal Strock

It was the winter of 1662, and Pierre de Fermat was a very angry old man. "Dammit," he cried, throwing the book across the room. "I came up with that theory first!"

"Which theory was that, dear?"  
Mme. Fermat solicitously picked up the

book and brought it back to him.

"The calculus. I discovered the method of tangents, but does anyone say, 'Oh, Fermat, what a mathematician'? No! It's always Newton, Newton, Newton. Damn that Englishman!"

"Now Pierre, you know it's not Mr.



Newton's fault. Why don't you take a nap?"

By this time, Fermat was really going. "What about analytic geometry? I did that too. But all they say is, 'Well, Descartes did most of the same work.' Descartes! He's nothing but a lousy philosopher!"

"Please, Pierre, Rene is a very nice philosopher. You're getting yourself worked up over nothing."

"Over nothing? How about probability theory? Pascal and I did a lot of that work together. But who gets invited to speak at all the scientific congresses? Who gets invited to lecture at all the universities? Not me!"

"Please, dear, remember your charity to your fellow man. The judge of history will win out, and you'll be remembered as the great mathematician you are. After all, you and I know you've done all that work. History will have to remember you for all you've done."

A light appeared in Fermat's eye, but his wife didn't notice—she thought her words had finally gotten through.

In a way, they had.

Fermat ran into his study and slammed the door. "History will remember me," he muttered. "I'll show

them. If they won't accept my genius while I'm alive, then let them puzzle over it after I am gone."

But how to do it? How to so turn the world upside down that his name would be remembered forever, without appearing to have done so purposely?

Fermat pulled volumes from the shelves, paging through them furiously, and tossing each aside as he reached for the next. Finally, his eye passed over a reference to the Pythagorean Theorem, and he laughed. "That's it! If they won't remember me for what I've done, let them remember me for what I haven't done."

He stumbled through the pile of books on the floor to his desk, grabbed a quill and dipped it, and, in the margin, scrawled: " $x^n + y^n = z^n$  no solution when  $n$  (integer)  $> 2$ . Wonderful proof, no room. Note to me: WRITE OUT THE PROOF."

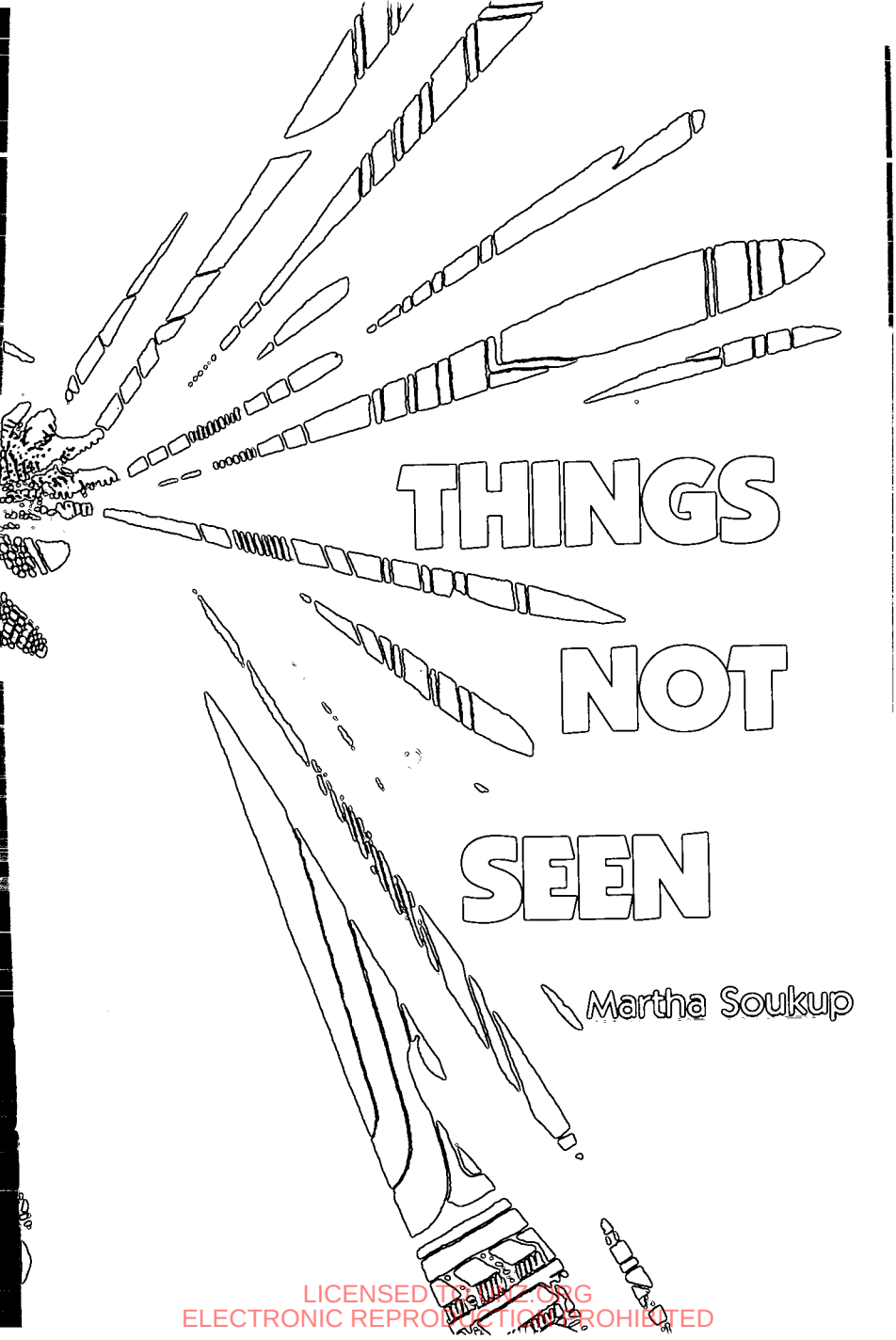
Fermat lived three more years, and was much more pleasant. He was generally happier, although less driven . . . except that he was constantly calculating equations, and then throwing the papers into the fire.

And Fermat made sure never to loan that book to anyone. ■

What anyone sees, of course,  
depends crucially  
on how he  
sees ...



Janet Aulisio



THINGS

NOT

SEEN

Martha Soukup

Her screen was slightly unbalanced toward green. It dulled reds, making it appear as if Dr. Herrera's face was streaked with chocolate syrup. Ginnie Erickson glanced at the security robot, which squatted near her hip, cabled into her workstation. "Hold it, please." The image froze. She hit a few keystrokes, until the blood was vivid red. "Take it at half speed." Herrera's head moved forward a bit, as though he were trying to peer through his gouged eyes, and he began to slump in his chair. "Quarter speed."

The viewpoint shifted crazily until Ralph Herrera filled the screen. Diagnostics—blood pressure, pulse—scrolled under the image of the dying scientist, measurements taken by the robot as it made itself into a temporary heart-lung machine, hooked to Herrera's circulatory system and oxygenating his blood.

Too late. His brain was scrambled by the ice pick that had stabbed through his eyes. The security robot was not equipped with an EEG, or it could have registered its charge's brain-death and saved itself some trouble.

"Stop," Ginnie said. There was nothing striking left in the robot's memory until ten minutes later, when Drobisch, the security chief, arrived. She might have continued in fast scan, but Drobisch was standing behind her. She'd seen that part already. The digital recording would show his hasty arrival, shirttail untucked, gun in hand. He would bend over the corpse and say, "Shit. Damn it, Herrera, if you've cost me my job—" It did not seem politic to play forward to that point.

"So what's wrong with the stupid machine?" Drobisch asked.

"I don't know. Give me some time."

"Time? Time?" She suspected he was related to someone, somewhere. Surely there was no other reason a twit like him could hold his job.

"It's a very complicated stupid machine." She turned to the robot. "You're a complicated machine, aren't you?"

"Yes," said the robot, its pleasant voice coming from a speaker in its chest. She'd known the guy who recorded its core model vocabulary. He said it had taken a week, but the results were worth it, easy enough on the ears that she'd dated the voice's original for two months. She was only slightly miffed that in her six years of working with robots, no one had ever suggested her voice would make a good model.

"So simplify it," said Drobisch. "The stupid thing says Herrera came in, sat down, and suddenly had blood and eyeballs all over himself. It's a stupid waste of money. And it's useless to the company until we figure out what's wrong with it."

"The back of my neck is warm enough, though, thanks," she said. Drobisch stared at her. "Could you stop breathing down it for a while? You're making me itch."

"I think I'll watch."

"Then could you tell me why the company is into investigating this thing? Why don't you leave it to the cops?"

"It's company business."

"What in the world was he working on? Why did he even need a guard robot?"

"Forget that, missy. It's classified."

"It might help me know who was

after him."

"That's none of your business. Your business is to figure out what's wrong with the stupid robot. Period. So do it."

Finally she ran the robot's memory forward through its entire futile attempt to keep Herrera alive. Drobish squirmed and left before the playback reached his arrival at the scene. Ginnie had the little office back to herself.

She stretched, sighed, and told the robot, "Let's take it from the top. Eleven P.M., Friday night."

Four hours later she hadn't gotten anywhere. Interrogating the robot and examining its visual memory gave her the same result: a headache. She leaned on the desk, flexing her tired wrists.

"When did the last person leave the lab besides Herrera?"

"Eight forty-six P.M., seventeen seconds," said the robot.

"That was Jane Yonamura?"

"Yes."

"No one besides Dr. Herrera was in the lab between then and when Drobish arrived at eleven twenty-six?"

"That is correct."

"Did Herrera look nervous?"

"Please contextually define 'nervous.'"

"Did he do anything unusual during that period?"

"He died."

Ginnie smiled. Literal-minded program. Others might anthropomorphize the robot, despite its resemblance to a large garbage can bristling with mechanical limbs and extrusions. She knew it was a sophisticated computer program housed in a wheeled mechanism. Real artificial intelligence was

still down the road.

"Did he do anything unusual during the last period he was alone, before he died?"

"He spent 87 percent of that period in the bathroom. These percentages are in the normal range for Dr. Herrera's late-night activities since I was assigned to guard him."

"Why were you assigned to guard him?"

"That information is classified."

"What was he working on?"

"That information is classified."

Ginnie shook her head and looked at her notes. *Yonamura leaves, 8:46:17 P.M. Herrera goes to john, 11:08:51. H. Back, 11:15:02. H. dead, 11:15:43. Drobish arrives, 11:26:25.* It was odd that Herrera was murdered right after he got back from the bathroom, but that didn't help. Did someone sneak into the lab during the six minutes scientist and robot were away? Possible, but it didn't explain how the robot didn't see that person murder the scientist in plain sight.

Another thing she couldn't understand was how Herrera could sit still while someone jabbed an ice pick through his eyes. She flinched just thinking about it. If he'd been drugged—but she'd been told blood workups hadn't found anything.

The robot had been instructed to tell her nothing that would reveal the nature of Herrera's work, but he had done nothing confidential in the hour and a half after his assistant left: there were no holes in what it told her. The robot's memory could be edited by a programmer, but any such edit would be recorded in deeply encrypted codes.

She'd checked them. Its memories had not been touched in more than two months.

Her eyes stung. Either she was feeling sympathetic pains, or she'd been working too long.

"Off," she told the robot. She left it cabled into her computer so she could start again first thing in the morning.

George looked up from her book when Ginnie let herself in. "Long day," she commented. Ginnie grunted at her twin sister, the one named after their mother's native state. Their father was from Virginia: the family joke was that Ginnie—Virginia—was Daddy's girl, and Georgia was their mother's favorite. It was a durable enough joke that Ginnie worked with computers, like her father, and George did medical research, like her mother.

The other family joke was how lucky they were no one was from New Jersey.

"You're telling me." Ginnie hung her jacket on her side of the closet. "Hey, this is your umbrella. Keep it on your side!"

"Picky, picky. Fabulous mood you're in tonight." George was her double—wide-hipped, narrow-waisted, with too much dark curly hair to keep under perfect control. Every time Ginnie looked at her, she wanted to brush her own hair.

"You ever have some jerk leaning on you about some impossible task, and you'll be allowed to comment."

George grinned. She worked at their mother's lab, so she was always expected to put in late hours. But they'd recently finished a major project and were taking some time off. "What's

up?"

"Get this. You know the guy who got killed the other day? The security robot completely flaked, didn't record the murder. I'm supposed to figure out what went wrong with it."

"Oh, now, that's interesting. Think you'll find out who killed him?"

Ginnie walked past her sister into the kitchenette. "That's 'none of my business.' I'm just supposed to find why the security robot screwed up." She took down a bowl and a box of raisin bran.

"Robots and computers. Very dull. The murder of Ralph Herrera, that's interesting. Hey, he's a fellow CalTech alum. You should catch his murderer to avenge the glory of our alma mater. And that's not a real dinner, you know."

Ginnie put the milk back in the refrigerator. "Tough. You cook a real dinner, I'll be glad to eat it."

"You order out for a real dinner, I'll be glad to warm it up in the microwave. So, the murder. Who offed him?"

"I don't know. Everything's very hush-hush. Drobisch—he's the security idiot, he's got to really be sweating his job—won't tell me why. Maybe he's not in on it either, I don't know. I don't know Herrera's work, I don't know his social life, I don't know if he had negatives of Drobisch in bed with his German shepherd. I just have to find the bug." She took a big spoonful of cereal. "Of course, the idea that they spent so much money for a security droid that can't even spot a murderer is probably reason enough. But then, they're hiding the robot from the cops."

"I hate it when you talk with your mouth full. That's what I'd sound like,

if I didn't have any manners. It's not a pretty thought, you know."

Ginnie crunched her cereal.

"Means, motive, opportunity," George said. Ginnie noticed belatedly that the novel George was reading was a Nero Wolfe. "You must know something we can deduce from."

"Opportunity, I don't understand. Motive, I haven't a clue. Means, an ice pick right into the brains and swirled around a bit."

"Ugh. Can the ice pick be traced?"

"That's something for the cops to do. I doubt it, though. I got a pretty good look at it in the robot's visual memory. It was an ordinary Sears ice pick."

"Fingerprints?"

"Smudged palm prints, from what I hear."

"Could be his, if he tried to pull it out. What makes you think the robot didn't do it? Aren't you worried to be around the thing?"

Ginnie shook her head. "I made sure to ask about that. There was brain matter on the ice pick. It would have got on the murderer's hands. There was none on the grasping limbs the robot could have used to hold the weapon, only blood and vitreous goop from the eyes. Anyway, the angle of entry was all wrong for a killer as short as the robot. Just right for a human murderer."

George marked her place in the Nero Wolfe and put it aside. "You're not bright enough to figure out the opportunity, and the means are mundane, if ugly. We'll have to work on motive."

Ginnie poured more cereal in her bowl. "I don't have to come home for this abuse, you know. I can go back to

work and get it from Drobisch."

"I'm better at it, though."

"Only because you have more practice, and perfect genes."

"Motive, motive. Did you know this guy at all from work?"

"No. He's just one of those people who comes in, works constantly, and goes home. He didn't exactly hang out chatting in the cafeteria. He was working on something classified, they say."

"So it could be industrial sabotage."

George frowned. "But why would a saboteur kill him in such a nasty way? Stabbing out his eyes. That seems so personal. Maybe symbolic. Like, oh, jealousy: 'You'll never look at another woman again!'"

"He doesn't sound like the lady-killer type," Ginnie said.

"That doesn't mean it couldn't have gone the other way around, right?"

"He's the kind of guy who spent all his time in the lab."

"So he was fooling around with someone in the lab, then. Was he married?" Ginnie shook her head. "So he's seeing someone at the lab, and she gets jealous. Maybe he isn't even fooling around on her. Maybe she's one of those crazed researchers who goes nuts after too much sleep deprivation."

"Maybe you are," Ginnie commented.

"Who's the last person who saw him alive?"

"His assistant, Jane Yonamura."

"Ah-hah!"

"Oh, come on, she doesn't look the type."

"They never do," George said wisely. "What's her line of work?"

"That one I do know. Before she was

assigned to Herrera, she ran the clone lab we use." Ginnie helped design roboticized diagnostic stations, translating BioInnovation's doctors' expertise into programs that could detect increasingly fine signs of medical disorder. They went through scores of identical rabbits, mice, and monkeys, testing the devices. Until she'd been tabbed to find a bug in a robot she'd had no hand in programming, the most frustrating part of Ginnie's job had been waiting the months it could take for a mouse genetically predisposed to a heart disorder to mature into symptoms for her programs to find.

"Tell you what," George said. "Herrera went to Tech years before us, but I'll bet I know some people from there who knew him. I'll call around and get the scoop on him for you. You should talk to Yonamura. Either she's the murderer, or she knows the other woman who's the murderer, or if something on their project got him killed, she may know about that, too."

"Drobisch will never let her talk. And solving murders isn't my job."

"You're a spoilsport. I'm going to call around anyway."

Ginnie went to get more milk.

She threw the printouts aside. "Gah!"

"I beg your pardon?" said the robot.

"It was, um, an interjection," Ginnie said. "It wasn't directed at you. It was directed at this damn documentation."

The robot was silent. It knew it did not have to answer a comment made to damn documentation, she thought.

Or to a lack of damn documentation.

BioInnovations had only been able to obtain the non-proprietary parts of the robot's software from its designers, since for whatever reason they didn't want it known the robot had failed to prevent a murder. Ginnie had called the guy she'd dated, the one with the voice, but he had only worked on the robot's speech software. He was no help.

The software documentation the other company had supplied was terrible. She didn't think it had been tampered with to help preserve trade secrets. She'd written too much overly hasty documentation herself.

She was looking in particular for a programming kludge that might have been written in to fix a bug the earlier programmers couldn't find, what she called the Use a Bigger Hammer school of programming. She'd done it herself, though never as sleazily as the programmer who, faced with a program that unaccountably would sometimes add two and two to make five, inserted code that said, *If  $2 + 2 = 5$ , then  $5 = 4$ .*

Anything that obvious would leap out at her, but it wasn't likely to be that obvious.

She also had to look for sabotage. So far the robot appeared to work the way it was supposed to, with no signs of tampering.

If she were actually working on solving the murder, rather than trying to find an invisible bug in a Byzantine robot, that could be interesting.

She leaned back in her desk chair. It creaked. "I've been listening to George too much." The robot swiveled to focus its attention on her. "I'm going to check on something," she told it. "Don't go anywhere."

"Noted," said the robot.

"Not possible," Drobisch said. His desk was enormous, a monster of dark-stained wood and iron trim.

"She was the last living person to see the robot working. She might have noticed something that would help me."

"She didn't."

"You're not the computer expert. Let me talk to her."

"We're concerned about her safety."

So you do think Herrera got killed because of what he was working on, she thought. "Look, I just want to ask her questions about the robot's functioning. Something that might look like nothing to you, and to her, might be the clue I need."

Drobisch glowered at her.

She rose to go. "OK. Maybe I can find this glitch anyway. It probably doesn't matter. The cops will probably figure out that portable heart-lung machine you hooked to Herrera was the second one. If they guess there was a robot at the scene, they'll impound it, and it won't be my headache."

"Wait," Drobisch said. Her hand was on the doorknob. She turned. "You can talk to her. At lunch, tomorrow."

As she'd figured. If she found the bug before the cops knew about the robot, they could erase all its memory and know they could safely use it again when it was finally returned. "Thanks."

"I'll be sitting in. Maybe I can help you." The sullen tone of his voice was a warning.

Jane Yonamura was a thin woman,

older than Ginnie, though it was hard to judge: maybe thirty, maybe thirty-five. She sat across from Ginnie at the cafeteria table, not meeting her eyes. Ginnie remembered that that was a characteristic of Japanese politeness. Otherwise Yonamura seemed American enough.

"I'm sorry about Dr. Herrera," Ginnie said. "Had you known him long?" Drobisch shifted in the chair beside her. You can damn well put up with politenesses, she thought. Anyone would ask that.

"We worked together for two years," Yonamura said. "I knew him as well as you know most people you work with. It's difficult to get used to his absence."

"I'm very sorry," Ginnie said.

Drobisch cleared his throat. Yonamura was silent.

"Did you notice anything unusual about the robot that night?"

"I really couldn't say, Ms. Erickson. I'm not an expert on such things. Dr. Herrera understood computers, but he was a very clever man. I'm an ordinary cellular biology expert; I only deal with computers and robots to the extent I need to for my work."

"That's what my sister always says, that she hates dealing with computers." Drobisch ostentatiously looked at his watch. "But she uses them more than she thinks about. I'm sure you noticed something."

"I can't think of anything."

"Well, you were working late."

"We usually did."

Just working? Ginnie wondered. Probably. They had a robot watching them for the last several weeks. "Did you have the robot assist you in any

way?" The robot had been instructed not to reveal anything about Herrera and Yonamura's work to her.

"No. Well, Dr. Herrera might have asked it to time some processes, or hold an instrument. Only very simple things."

"That's good. Did it have trouble understanding any of his instructions that night?"

"No. Let me think about that. No, I really don't think so. As I said, he never asked it to do very much. I'm not even certain he talked to it that night."

Now, you'd remember what Herrera did the night he was murdered, Ginnie thought. It was only five days ago, and it had been a memorable night. "It'd be a waste to have such a state-of-the-art robot around and not have it do anything to help out, wouldn't it? I mean, I wonder what the accountants thought about OK'ing such an expensive piece of machinery. I guess you guys were doing something important."

"I suppose someone thought so," said Yonamura, impassively.

Ginnie could hear Drobisch breathing. The man breathed loud. He must have practiced being noticeable.

"Did either of you talk to the robot? Did it say anything?"

"It might have. I don't recall."

"I was going to ask if it was showing any difficulties with language, or if it stuttered, or repeated itself. You don't remember if it spoke?"

"I don't," Yonamura said.

"What about its movements? Did it seem to have any trouble navigating?"

"Not to the best of my memory. It isn't something I'd have paid attention to."

"You're not getting anywhere here, Erickson," Drobisch said. "We all have work to do."

No kidding, I'm not, Ginnie thought. Yonamura was polite, but opaque: deliberately so, she was sure. That might have to do with Drobisch's presence. Perhaps.

"Thank you anyway," she told Yonamura, who smiled slightly and accepted Ginnie's handshake.

"It's driving me crazy," she told her sister. "Three days of this, and the robot makes no more sense than ever. No—the robot makes as *much* sense as ever. And it's probably got a hundred man-years of software in it. I could be looking forever." She rubbed her face, yawning. "If only they weren't too paranoid to bring in a team of people to look over the thing. The best way to spot a bug is to bring in a new perspective, but I can tell Drobisch doesn't even like having one person look at it."

"You saw Yonamura?" George asked.

"Oh, yeah. Speaking of brick walls, that woman's not going to talk about anything."

"Buried passions?"

"Buried everything. I can't guess what kind of secrets she's keeping. Maybe she just has more respect for non-disclosure agreements than I do."

"Hey, if you can't tell someone who shares your genetic material, who can you tell?" George said. "I'll never tell. Let them think I'm you."

"You wouldn't pass the retina ID check they made me take when I signed all those forms."

"So I won't let them stare deeply into

my eyes. They'd never check. Even if they thought about you having a twin, the world's full of idiots who think twins have the same fingerprints and retina prints." As teenagers, George and Ginnie had read too much science fiction about clones, who were nothing but high-tech twins, not only having the same fingerprints, but lockstep personalities. They hated that. "Here's your surprise bonus today for having a nosy twin." George tossed a bound document on the kitchen table.

"What's this?"

"I drove over to Tech today to see if anyone had any old gossip about Herrera. Nothing. He had a girlfriend junior year from City College, but it didn't last." Ginnie snorted. She'd never thought much of guys who had to leave campus to get girlfriends. "So I looked up his doctoral dissertation, just so it wouldn't be a complete waste of time driving to Pasadena."

"It's always a waste of time driving to Pasadena," Ginnie said automatically, picking up the binder. "Induced Heuristics and Rote Learning in Mammals"? Sounds like a page-turner."

"I still say Yonamura did him in, but if they weren't hot and heavy, and it was sabotage, this could be a clue to whatever they were working on."

"It was twelve years ago," Ginnie said. "It could have nothing at all to do with whatever he was doing for the company." She flipped through the pages. "And it's really badly written. Do they make you write dissertations this way? Thank god I didn't go for a doctorate."

"I had a look at it," George said. "There's some theoretical stuff about

ways to treat people who've lost abilities due to strokes or other brain trauma."

"Like ice picks?"

"Ick. Like, say, someone has a microstroke, and can't tie his shoelaces anymore. Herrera thinks it should be possible to zap the whole subroutine for tying shoelaces into a brain."

"How?"

"I'm going to reread it. It's pretty thick going, and I never read much neurology. Most of this paper is about white rats and bunny rabbits. He only mentions people toward the end."

"That's the interesting part, though, isn't it?" Ginnie said. She squinted at a thicket of graphs relating in some way to brain chemicals she'd never heard of. "Programming human brains. Just think how a military organization would slaver over that."

"I have," George said. "So industrial sabotage goes back on the motive list. And so does international intrigue."

"Oh, great," said Ginnie. "Now I prefer the theory about a sex-crazed research assistant stabbing his eyes out."

"Either way, poor sap. Wonder if he saw it coming."

"It could explain why Yonamura is so quiet. This might be dangerous business to know anything about."

"If it's related to what Herrera was working on for BioInnovations," said George.

"I'm going to ask around some more. Maybe he told someone what he was working on."

"Listen," Ginnie said. She knew she couldn't stop her sister from working a puzzle through to its finish. She was

intrigued herself, but she was also feeling queasy. She reached across the table and took her twin's hand. "Be careful."

George smiled and squeezed her fingers.

She was running the robot's memory through the last ten minutes before Herrera's death. The picture jiggled as the robot trundled through the hallway behind the scientist. Herrera went into the end stall of the men's room; the robot focused on the door. Someone had taped an old Gary Larson cartoon to it, so yellowed it was brown: it showed a laboratory filled with dead cats in lab coats. Curiosity, it seemed, had killed them.

Herrera came out of the stall and walked briskly out of the bathroom. He did not stop to wash his hands. Ginnie shook her head. The robot had to hurry to keep up. He stopped at the lab door, and the robot preceded him into the room and took up its customary position in the corner opposite the door, from which it could see everything. Herrera walked into the room and sat at his terminal. She isolated the keyboard in closeup. The keys Herrera hit were *A*, *6*, *Caps Lock*, *Shift*, *J*, *Y*, *Delete*, *G*, *H*, *2*, *Tab*. The sequence looked nonsensical. She frowned.

That was the point the door suddenly slammed shut; the robot glanced at the source of the sound, only for an instant.

Gore was running from Herrera's eyes when it glanced back.

Someone cleared his throat behind her. "You have two days."

"Two days until what?"

"I've spoken to your department,"

Drobisch said. "Your supervisor agrees they're overextended in salary base. He may not be able to keep you on."

"Wait a minute."

"I've told him, of course, that since you've been on loan to the security department, we'd like to help. We might be able to squeeze out some money to move into their budget. Out of gratitude. If we were grateful."

This was nearly a subtle move. She should be impressed. "Come on. We're not talking about a payroll program. There are reams of code in this robot. You can't expect one programmer to find a bug in a week!"

"There are a lot of programmers. BioInnovations can't be expected to employ them all." Drobisch looked smug. He turned on his heel and left.

"Damn it!"

He was setting her up to be the fall guy. Not his fault the security robot didn't work: the company employed idiot programmers who couldn't work the thing. No matter she'd hardly seen the robot before the murder. She suspected Drobisch was in a position to alter her employment records.

He was right about one thing. Southern California, which ten years ago had looked like a bottomless pool of employment for good programmers, was finally saturated with them. And even when you lived with your sister, rents were outrageous. It took both of them to afford a two-bedroom place. The cost of water alone could break her, if she went long without a job.

She might even have to move to New Jersey.

"Damn it."

\* \* \*

"We're not going to talk about me finding a new roommate," George said firmly. "We're going to solve this mystery."

Ginnie was lying on the sofa, her arms wrapped around a cushion, thinking. "If I have to move out, Mom will want you to move back with her."

"Not a chance. I love Mom and all, but give me a break. It's nice not to have talked to her for a week, for a change."

"You haven't told her? Good. She'd just worry. Did you find out anything about Yonamura?"

"No." George bit her lip. "I'm afraid I sort of wasted today. I wish I'd known Drobisch was going to lean on you."

"Well, you didn't know."

"Yeah, but if you lose your job—I was talking to some Lloydies about Herrera, back when he lived there. You know he lived in Lloyd House, just like I did?"

"No. Small world." Ginnie had an old college friend who'd dropped out of physics and started a small import business up in Oregon. Maybe he could use a programmer to make the shipping end of it more efficient. If she could get used to living with pine trees. Or maybe she could get a job on the loading dock. She hugged the cushion to her cheek.

"They were telling me stories about his Ditch Day stack. It was pretty memorable."

On Senior Ditch Day at CalTech, the seniors set puzzles, called "stacks," for the underclassmen to solve. The underclassmen had to solve the puzzle to gain entry to the senior's room. If they didn't find a "bribe"—usually junk food

—waiting for them there, they had the right to counterstack the senior's room, giving her a taste of her own medicine.

Ginnie, distracted by killer finals, had simply thrown together a quiz for her stack. When the group trying to get into her room answered some trivia questions on her computer and solved what she'd thought was a fairly knotty programming puzzle, the computer told them where they could find her room key. She'd left a keg of beer and ten pounds of chocolate in the room, and when she got back from her Ditch Day trip to Disneyland, she found nothing but candy wrappers remaining of the bribe.

She still regretted not taking the time to come up with a finesse stack, something the underclassmen would bash their brains against all day but which would be obvious, in light of the clues, when they found out what it was.

"They got to his room and found a video monitor and a joystick outside the door," George said. "And a note that just said, 'Get the key or solve why it can't be done.'"

"Sounds like a good one," Ginnie said, interested despite herself.

"When they turned on the video monitor, it showed the interior of his room, like the camera was next to the door. It looked ordinary enough, but the floor was entirely cleared, and in the middle of it was the room key, and this little cart, with an arm in front and an antenna sticking up.

"Yeah, one of them picked up the joystick and moved it around, and the cart turned around with it. One button on the joystick raised and lowered the arm, and the other made the cart go

forward or backward. The arm had a magnet on it, and there was a washer taped to the key, so the magnet could pick it up."

"Too easy. There's a catch."

"You bet. It looked like the idea was to maneuver the cart over to the door with the key, and get it to push it out under the door. But they couldn't quite get the cart to work right. It'd start toward the door, and suddenly veer off in the wrong direction. Or it would stop moving. Or the key would fall off."

"Some kind of kink programmed into the cart's movement."

"They thought of that. They plotted all the unexplained movements and looked for a pattern. Like, if you turn it 180 degrees to the left, maybe it would go backward. Well, it did sometimes, and it didn't sometimes."

"So it had random error programmed into it, and that's why they couldn't get it to work?"

"But how do you 'prove' that? It's a finesse stack: there has to be something big and deceptively obvious they can point to, or Herrera's screwed it up. They're starting to get very annoyed, because they can see the room and they don't see a bribe in it. These are students who are seriously looking forward to skipping the counterstack and just trashing his room if they solve the stack. It looks like he expected it to be impossible to solve, and that's not fair."

"What did it turn out to be?" Ginnie asked.

"Think about it. There are three components of the puzzle they can look at: there's the remote-controlled cart, and the joystick, and the video monitor/camera setup. They can't get to the cart,

except by experimenting with the joystick and watching on the monitor."

"The joystick."

"They took it apart, carefully, and looked at it. Nothing funny in the joystick that they could see."

"The monitor?"

"It was late in the day when this one bright freshman began to wonder if the monitor was showing them the whole story. Some big-shot junior guy had the joystick, but she finally talked him into handing it to her. She moved the cart all the way to the back wall, and started to make it go back and forth, against the wall, as fast as she could."

"What did that prove?"

"In the middle of the room, the cart blinked out of existence on the video monitor. She moved it back, and half of it was gone. Then it came back again."

"You've lost me."

"Remember when we were kids watching a weather report, and the reporter was wearing a green tie, and you could see Indiana right through it?"

"I—oh! It was a chroma key setup!"

"She pounded on the door and shouted 'Open up, Ralph!' and Herrera opened the door from the inside. The whole back wall of the room was draped in green, he'd painted the floor green, and he was wearing a green bodysuit and a green hood."

"Yep. She'd proved why they couldn't get the key. It was one of those old-fashioned setups that screened out greens, the kind they used when they wanted it to look like the weather guy was standing in front of a weather map or a live shot of a sunset or something."

"I suppose he could find all the equipment for that on campus," Ginnie

said.

"Actually, I think he salvaged it from a station that was upgrading its technology. Just like on the weather report, where the camera saw green, the chroma key showed a video image he'd taken earlier instead, of the normal back and floor of the room. So in his green cover-up, he was invisible to the camera. As long as he stayed behind the cart, from camera view, he could mess with its movements without being detected."

"Not bad."

"There's this big lump covered with green cloth in the back of the room, and he rips it off: champagne on ice, this big pastry spread, the works. He sort of cheated by not having actually ditched on Ditch Day, but he sounds like an OK guy. It's too bad he's dead." George sighed. "He had chocolate eclairs for them. I never solved a stack that got me chocolate eclairs."

"Huh." Ginnie sat up and put the cushion down. "So there was one other factor in his stack puzzle, besides the cart, and the joystick, and the camera and monitor."

"Which is?"

"Him. Herrera."

"Good morning, Erickson," Drobisch said.

"Morning," she said, smiling.

She seemed awfully confident for someone who would be canned in eight hours, he thought. She wasn't bad-looking, but she had an attitude problem. "This is your last day, you know."

She smiled again and walked the other way down the hall. He put her out of his mind.

"Good morning, Mr. Drobisch."

"Morning," he grunted. He was almost at his office when he turned around. Who was that? Red suit jacket, blue jeans, brown hair. Erickson? Hadn't he already seen her?

Drobisch hated *deja vu* in the morning. He decided he needed another cup of coffee. Yonamura could not be allowed to talk to anyone. He'd spend today making sure she knew that. It was an aggravation: no wonder he was distracted.

"This is to distract it." Ginnie held up the sound synthesizer. "It has about twenty seconds of silence programmed in before it shouts bloody murder. So timing's important on this experiment."

"Got it," George said. "You want me to walk over and sit in this chair? That's it?"

"That's it. Do it as smoothly as you can. Take even steps."

"OK. Ready when you say."

"Now," said Ginnie. The robot was cabled to her workstation, on idle. She toggled it on with the joystick she'd rigged.

George walked across the room. The robot watched. She sat.

Ginnie waited a beat. Then she walked across the room, toward George. As she neared her twin, the sound synthesizer cried "Help! Burglar! Murder! Stop!" The robot swiveled toward the alarm. Ginnie toggled it back to idle.

"Let's see what we've got," she said. "You wait outside. I don't want it to see you again."

She turned the robot on again. "When did you last see me?" she

asked.

"At 9:09 this morning."

"What did I do?"

"You entered this room. You walked to the northeast corner and sat down."

"How many times did I cross the room to the northeast corner this morning?"

"Once."

"Once?"

"Correct."

"Do you know what you've got, robot? You've got some let-five-equal-four code. You've got a kludge, and I know who else knew that. Maybe two people who knew that."

"Do you require a response from me?"

"No, thanks. I've already got everything from you that I need." She turned the robot back to idle and hit the codes on her keyboard that would allow her to erase its memory of the morning's experiment. They could find traces of the editing, but maybe they wouldn't bother. With any luck, the robot would be in the scrap heap tomorrow.

"You can come back in."

"Good," said George. She shut the door behind her. "All your coworkers are staring at me. I think they're wondering why you're spending your morning standing outside your office. Did you get what you needed?"

"Yes," said Ginnie. "I'm almost certain what happened. I just need to pry Drobisch loose from Yonamura long enough to talk to her."

"Oh, that sounds like fun. Remember third grade, when we'd confuse Ms. Jefferson who was who?" George picked up Ginnie's extension. "Drobisch, please." Pause. "He's not in his

office? You'd better page him and tell him to come see Virginia Erickson right now. No, this will not wait. Now!" She slammed the receiver down.

"How will you hold him?"

"I'll threaten a civil suit for wrongful termination of employment. I can double talk on that for at least half an hour."

"I owe you several."

"Nineteen, now. But who's keeping track?"

Yonamura was peering into a microscope and did not look up. "Mr. Drobisch, we've nothing to talk about. I've told you everything I know."

"I don't need you to tell me everything, Dr. Yonamura."

"Ms. Erickson?" Yonamura pushed her hair back. "I don't think it's a good idea for you to be here."

"Is it bugged?"

"Bugged? Oh, you mean a microphone. No, I don't—I don't think so. I think I found it." She avoided Ginnie's eye, as she had the first time they met. "I really have nothing to tell you about your robot."

"I want to mention a couple of things to you. I want to know if I'm understanding things right. If I do, you have nothing to worry about from me."

Yonamura was silent, watching her.

"I've seen Dr. Herrera's dissertation. It was about an idea called 'induced heuristics.' I don't know what you brought to the project, but I want to guess. I want to guess you can force-grow clones to early maturity."

"I don't know why you think so."

"You might want to know that I've discovered a bug in the robot after all.

Actually, I've discovered the programming fix that covers up a bug."

Yonamura folded her hands in her lap and waited.

"I think when they were designing the robot, it had a glitch that made it think it had seen the same thing more than once. A sort of robot *deja vu*. If you rolled a ball in front of it, it might think it saw that ball roll by twice, or, worst case, it might get stuck in a loop and see nothing but that ball roll by, an infinite number of times. That would be a problem."

"I suppose it would. It's not my specialty."

"Dr. Herrera understood computers, though. And perception, and behavior. He needed all of that for the work you were doing, didn't he? You grow the clones, he works on their brains."

"Dr. Herrera's work was classified. And difficult. Even if I were at liberty to explain it to you, I wouldn't be able to."

"That's OK. I'll make a crude guess. Herrera was inventing a way to put behaviors into empty brains. Like the brains of force-grown clones. It's the only thing I can think of that explains why Herrera's still alive. Are you in contact with him? Do you know where he is?"

Yonamura leapt to her feet. "Ms. Erickson! Dr. Herrera is dead! How can you say—"

"Settle down! I'm just babbling nonsense. Not even worth repeating outside this room. Just let me finish. If you two were working on a project to turn blank-minded clones into programmed zombies, and if he wanted out—if he didn't like what he thought was going to be

done with it, but he was afraid BioInnovations or its clients would go after him if he ran—you could use the robot's little undocumented feature."

Ginnie licked her lips. Her mouth was dry. She'd tried not to think through the implications of her solution, but she couldn't avoid it now. Yonamura looked like she wanted to run.

Ginnie said, "Here's where I get really nonsensical: You've developed a way to force clones to rapid maturity. You've made a Herrera clone, all grown up but no mind to speak of. With his neurochemicals and electronics and whatever, Herrera gives it a simple program: stand on this toilet until tapped on the shoulder, leave the bathroom, walk down a hall, go into a room, sit in a chair, hit some random computer keys, wait."

"The real Herrera, dressed identically, follows immediately behind the clone, careful to walk the same way the clone was programmed to."

"Now, here's the beauty part: he knows, maybe from noticing the way it perceived little cloned, behavior-programmed bunnies, that the robot discounts anything it believes it's identically seen, immediately before. Completely discounts it. Doesn't perceive it. That's how its programmers kludged the *deja vu* bug."

Yonamura sat, slowly.

"All he needs is to distract the robot long enough to stab into his clone's nearly blank brain, incidentally destroying the clone's unique retina patterns, in case anyone thought to check. If he ducks out of sight quickly enough, when the robot's first-aid functions take over, it won't have time to see him es-

cape. While its kludge kept it from perceiving him come in."

"You can't prove any of this," Yonamura said quietly.

"They didn't put the robot on him to guard him from the competition, did they? That was a side-benefit, but they really wanted to make sure he didn't try anything funny. The robot was there to report if he did, and to intimidate him so he wouldn't try it in the first place."

"That's what we thought." Yonamura's tone was even.

Ginnie had to work to keep her own voice low. "Our advantage is that Drobisch wants to bury any evidence that might show Herrera's death was his fault. If you stay quiet, you may be OK."

"Dr. Herrera was the only person who fully understood his theories. I'm counting on them not watching me quite as closely. I'd planned to get away as soon as he had enough time to cover his tracks. We weren't counting on the fraud never being discovered. We only hoped, if they thought a competitor had killed him, that it would give him enough time."

"I hope it does. I don't want to know how much money is involved in this. I don't want to know which governments would pay for this technology. I do have one question."

"What?" asked Dr. Yonamura.

"Herrera's techniques—were they only useful on blank brains? Or could

they be used on your brain, or mine?"

Yonamura looked Ginnie directly in the eye. She said nothing.

George was gone when Ginnie returned. It took less than half an hour to find the kludge in the robot's code, now that she knew what to look for. She made a simple deletion. Then she packed her personal effects.

"Erickson!" Drobisch thundered. He stormed through her doorway. "You are finished at this company. You are finished everywhere. Your work record shows inefficiencies that—"

"You're right, Mr. Drobisch," Ginnie said. She nodded at the security robot, which stared unmoving at the doorway, watching images of Drobisch storm in again, and again, and again. "I not only didn't find the glitch in the security robot, but the bug seems to have gotten worse. It's a mess."

"Goddamn stupid machine! I told them not to—"

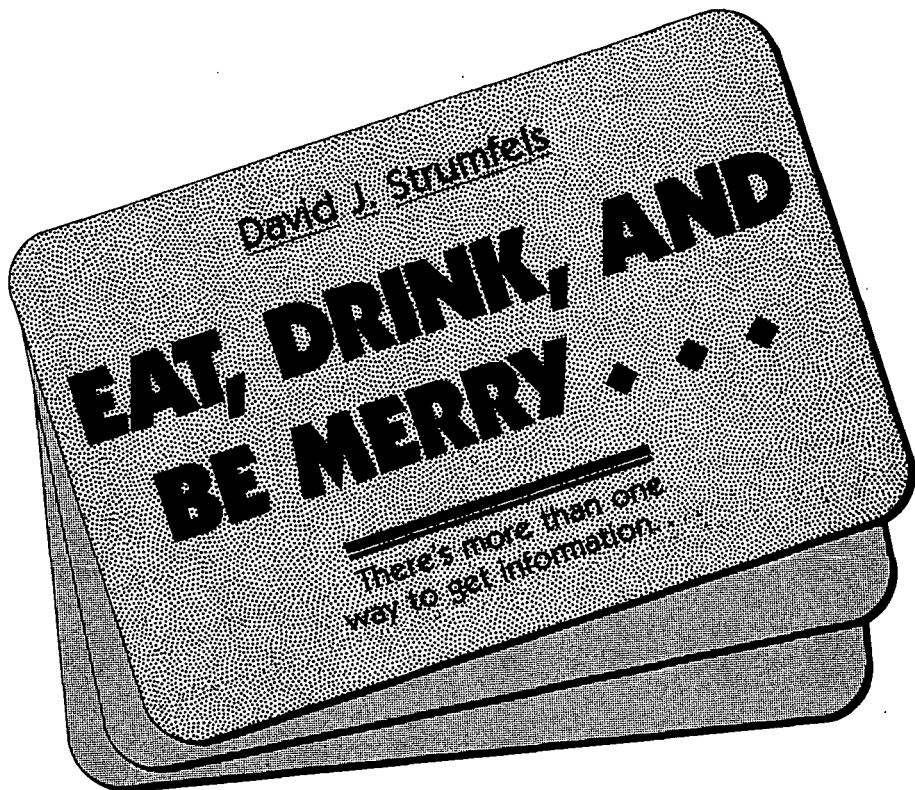
"You were right. Under the circumstances, I think I should give my notice." She picked up her box of personal items and squeezed past him as he gaped at her.

Would Drobisch be more interested in burying anything that would make him look bad to his superiors than he was in following her? It was a fair bet.

Oregon or New Jersey? She wondered which one Herrera would choose. ■

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●Our patience will achieve more than our force.  
Edmund Burke



President and chairperson of the board Reginald X.S.Baggage III stood before his subordinates, his chubby pink face gleaming: "Well gentlemen, as daddy would have said, I believe this calls for a drink."

The champagne was uncorked, the glasses filled, and the old board room with its oaken just-about-everything, and pennants and coats of arms and knightly armor in each corner, was reverberating with the tinkling of the finest crystal.

"To our greatest—er, most profitable—creation: FutureCard™!"

\* \* \*

Elliot Demming-Jones, the firm's official spokesperson, gazed beneficently at the dedicated men and women of the news media who had gathered before him. "As you know, ladies and gentlemen, the main problem in providing credit in these days of increasing irresponsibility is that segment of the public which believes it has some inalienable right to purchase what it has neither ability or willingness to pay for; a segment which, alas, has grown to the point where even the honest citizen can no longer obtain credit without subjecting him or herself to the most distasteful invasions of privacy.

"The FutureCard has changed all that.

"Thanks to FutureCard, no one need ever again fear applying for credit again. I can personally guarantee you—all of you, whoever you are, or wherever you are—that to apply for a FutureCard is to receive it, on the spot, with no embarrassing questions asked, no investigations, and no legal waivers to sign. And to receive it with full privileges at the time of issue. You won't even be asked for your name, social security number, fingerprints, or even a cell sample. You walk into our offices anonymously, and you walk out anonymously. Indeed, once we finish compiling our mailing lists, you won't even have to do that. Why, even as I speak, the first fortunate individuals—chosen randomly from the last census I might add—are already receiving their, shall we say, passports to the future. That's how much faith we have in FutureCard."

Cornelius Harbinger, Ph.D., director of research, cleared his throat noisily. "Naturally, I cannot reveal the details of our process, but I don't think any of you will be surprised to hear that it is based on tachyonics. When a purchase is attempted using the FutureCard, the card examines the customer's timeline out to a distance of five years, and determines whether payment was—er, will be—made on a timely schedule. If not, the purchase is rejected automatically."

Questions? Oh, there were questions galore. Fortunately, Dr. Harbinger had anticipated most of them.

"The answer to that is a resounding no. The card can only view the future

timeline of its authorized user; and then, only with respect to his/her ability and willingness to pay. In no way can it be used to predict the future generally—to, say, tell us what the stock market will be doing next year, or who will win the Super Bowl. There are good reasons—theoretical reasons—why tachyonics can never do that. I assure you, it is quite impossible. Quite."

Melvin Fishminder (not his real name), the notorious con artist whose latest triumph was in persuading the federal government that he was a failed Savings and Loan—he wasn't able to keep the ten billion unfortunately, but the day's interest would keep him in Havana for another six months—dragged himself out of bed to see what fascinating new possibilities the mailbot had just dropped off.

"I'll be damned. . . ." He couldn't remember the last time he'd been offered even an application for a credit card. Yet the shining gold rectangle lay in his hand, eager to serve his every want. Suddenly suspicious, he rummaged through the rest of the envelope's contents, but found nothing to indicate that the card wasn't really his, or that there were conditions attached to its use that a man of his—delicacies—couldn't possibly agree to. Of course, it could have been a trick. . . .

For three days, he agonized over that possibility, until he decided that there was only one way to find out. Anyway, he'd been wanting one of those new Korean super high resolution holovisions for some time. Slightly nervous, he handed the smiling roboclerk the card, and watched as it slid into the bot's

reader and communed with databases all over the world. Certainly, it had to reject him. . . ."

"Very good sir. Will that be pick up, or do you want it delivered?"

"I'll—be—damned."

"Sir?"

"Er, nothing. Uh, pick up. Absolutely."

Senator Roy Lee Barnacle was going over next year's proposed NASA budget, and frowning with dismay. "What's the matter with these scientist types anyway?" he muttered, to no one in particular, although each of his aides thought he was addressing them. "Don't they realize this country's runnin' half *trillion* dollar deficits a year already? I mean, look at this: a billion smackaroos just to move around some little chunks of rock in space. A billion! Where do they think we're supposed to get a billion dollars from anyway? Thin air?"

Disgusted, he flipped to the next page. Where more bad news awaited him. He pounded a soft fist against his desk. What was the matter with those people over in the Department of Energy anyway? Couldn't they see how desperately the country needed methane digested from chicken manure? "Only two billion?! Over my dead body!"

Lois Lipps sat in her supervisor's office and waited for him to finish reading the figures she had compiled.

When he'd finished, he handed the palmtop back to her, and cleared his throat. "Well, that is a very interesting report, Ms.—ah, Lipps. Ah, was there anything else you wanted to discuss?"

*He doesn't see it!* she realized silently. "Mr. Turbess, I really think you should look at those figures again. If you ask me, they clearly suggest that we're in trouble—perhaps big trouble."

Turbess raised an eyebrow, and started tapping his fingernails together. "Really Ms. Lipps? And what makes you say that?"

"What makes me say that? Look at some of those people whom we've been giving credit to! Most of them have bad ratings going almost back to the day they were born. Some even have fraud convictions on their record. Giving them credit is throwing money down the sewer."

"Really, Ms. Lipps, don't you think you're overreacting just a bit?"

"Overreacting?" What she really wanted to say stuck in her throat like a fly caught in a spider's web.

Turbess smiled unctuously. "FutureCard only examines future ability and willingness to pay. That's all it cares about; and if you think about it, that's all we care about—whether or not a customer will pay what he owes us. The past is of no consideration whatsoever."

"But—but—we're talking about some of the worst credit risks on five continents!"

All this elicited was a thorough head shaking however. "Ms. Lipps, you're missing the whole point of FutureCard. There are no risks anymore: every credit assessment is a sure thing; we either know the client will pay, or we know he won't. What difference does it make whether he has paid in the past?" He tapped his forehead. "Think about it. Think very carefully about it."

"What you're telling me," Chief Engineer Norman Roddery said to the trio of concerned faces before him, "Is that you can't tell me for sure whether one of those chunks is going to hit us or not."

Two of the faces remained silent, but one was less restrained. "What do you want from us, Norm? There are thousands of those chunks headed our way, and they're all indistinct blobs in our ground scopes; how are we supposed to calculate the exact path of each one of them?"

Roddery groaned. He saw it coming again, but didn't know how to avoid it. "I still don't understand why you're trying to do it with ground scopes. I thought the new Hubble was operational." That had been their argument before, all the delays and glitches they threw at him every time he breathed that magic name. But Goddard had publicly declared the Hubble 100 percent almost a week ago.

"Yes, well, I suppose that's the official line. The truth is something else however."

Roddery felt a spasm of bile beneath his heart. "Are you trying to tell me that something is wrong with *this* telescope also?"

"Hey, don't look at us like that; it's not like it's our fault, you know. . . ."

"Congratulations Mr. Fishminder: you are now the proud owner of a brand new Mercedes."

Fishminder accepted the tingling keys from the dealer. His hands were wet with perspiration. "I'll be damned. I'll—be—goddamned."

His first thought was to take it down to the casinos, but that plan lost its glitter almost immediately: sure, he'd been a big shot at first, but once everyone started showing up with their golden passes, the women started finding his something less than good looks decisive again. He didn't enjoy being reminded why he'd gotten into his particular line of business in the first place.

Besides, greater men ought to have greater ambitions. And he'd heard that you really could buy an entire South Seas island, complete with coral reefs, endless white beaches, palm trees, and perhaps even a beautiful Polynesian servant or two.

Elliot Demming-Jones stood before the armada of salivating journalists, and boldly spoke the raw, unseasoned truth. "I repeat, ladies and gentlemen, there is absolutely no truth to the rumor that the firm is in any serious financial difficulties because of FutureCard. It is an absolute and utter falsehood, devoid of even the smallest morsel of fact.

"I should add that we have, in fact, traced the source of these ugly allegations. They have originated with a disgruntled employee, who was recently dismissed due to inefficiency and an inability to work as part of the family we like to consider ourselves. At the time, we thought the parting was amicable, but apparently we were mistaken.

"What was that? Are we taking legal action against the employee? The answer to that question is, after considerable and searching deliberation, we have come to the conclusion that there is nothing to be gained by placing an obviously disturbed individual and her

family under even greater strain. This has, after all, been a great embarrassment to everyone involved; we see no reason to drag undeserving people through the mud, so to speak. Therefore, we will not be taking legal action.

"I should like to repeat at this juncture however, that again, there is no truth to these rumors of financial insolvency. The firm is rock solid, and we expect to be satisfying both our customers and our stockholders for many profitable years to come. Thank you."

When Lois Lipps heard these statements, she carefully compiled and cross-linked all the data she had pirated from the firm's database, and then just as carefully put in a call to the SEC. She did not know, of course, that while she was doing this, Dr. Harbinger was studying a hypersheet analysis of that same data and shaking his head.

"Is that all you can do Harbinger, shake your head?" Morris Mobius, vice-president in charge of Operations, chewed on his cigar and followed the undulations with increasingly pink jowls. "Damn it man, I need answers, not nut wagging! What's wrong with your bloody cards?"

Harbinger stopped shaking his head, but all he could offer for the demand was a shrug from his slumped shoulders. He didn't take his eyes from the sheet. "There's nothing wrong. Nothing. I've tested it a hundred different ways. The tachyonics work perfectly. The theory is right." He shrugged again.

"That's not good enough Harbinger," Mobius barked through his teeth. He pointed a thick, well manicured finger at the scientist. "I'm giving you two

days. Two days. If you don't have answers by then, you're fired. You understand that? Fired."

Harbinger wasn't listening however. "There's only two possibilities. Either the card holders really will pay; or—or—"

His slump suddenly ended. Eyes popped wide.

"Or what? For Christ's sake man, *what?*"

"Or the AI is deciding—hmmm—yes: I believe that could be it!" Harbinger finally acknowledged his superior's presence. "Look: the tachyonic algorithms only decide whether granting a specific credit request will result in a net profit or loss for the firm; as long as it's not a loss, the request is granted."

"I know that," Mobius snorted. "Do I look stupid? That was at management's insistence, if you'll recall."

"Really? I hadn't known—never mind. The point is, if all requests are being granted, that suggests, not that they'll all be paid, but that it doesn't matter one way or the other: the firm's future profitability isn't being affected positively or negatively. See what I mean?"

The cigar, which had been twirling restlessly in Mobius's lips, came to a dead standstill. It was several moments later when Mobius removed it, and then methodically crushed it in the crystal mortar that was Harbinger's only desk ornament. The VP then froze Harbinger with a level stare. "Exactly what, Dr. Harbinger, are you trying to say?"

But Harbinger was shrugging again. "I don't know. I really don't know." He took a deep breath and let it out

in a painful sigh. "Maybe someone at Berkeley or MIT will have some ideas. I ought to . . . What are you looking at me like that for?"

"You mean, you've been talking about this outside of the firm?"

"Well—I mean, of course I have. What did you expect?"

Mobius picked up the cigar butt and flung it across the room. "You can forget those two days Harbinger. *You're fired!*"

Actually, Harbinger had talked to only one person, an astrophysicist at Berkeley who happened to be a personal friend. And at the moment, that friend wouldn't have been much help anyway, as she had also been handed a diskful of recalcitrant telescopic image data and asked what she could do with it. Which turned out to be frustratingly little: no matter how she transformed it, deconvolved it, smoothed it, interfered it, or time-resolved it, she simply could not tease from it anything better than an educated guess about whether any of those chunks were going to hit the Earth or not. All of which was very unsatisfactory to Norman Roddery, who knew the only way the Barnacles of this world were going to listen was if he could show them irrefutable proof positive. "Is that the best you can do?" he sighed. "That's all?"

She assured him that it was.

The conversation ended unhappily. She plopped her head between her hands and stared out her office window across the bustling yet peaceful campus. Why did I ever get into this work in the first place? she thought to herself. It's 1 percent inspiration and 99 percent frus-

tration. Why didn't I become something easy, like a lawyer, or a veterinarian? Or business. That's it: I should have gone into business.

If only she could let go of the problem, now that she had admitted to herself that she was licked. But no: her mind would keep spinning around and around like a top exempted from the laws of thermodynamics. There simply *had* to be an answer. Had to be. That was the guiding principle in her life, the singular obsession which had driven her all the way through school, post-grad work, and the rigors of tenure, despite the funny looks and cleared throats of those who had never heard of a *female* astrophysicist. It was her damnation, her sentence in hell. There had to be a way to do it. There was always a way. If the top spun long enough—

She raised her head. Frowned. No. Or—could it possibly—

She pulled out the data and reviewed it again.

But—but it wasn't supposed to work that way. Tachyonics could only access the narrowest of timelines. The information it gave you was both specific and limited. It couldn't—

*Data and information are not identical.*

That was what Professor Ackery had always drilled into her. A piece of data by itself had very little information content; while what information it could contain depended almost completely upon what other data you possessed. Information was holistic.

Holistic. Licking her lips, she started drumming her fingers restlessly on her desk, at first slowly, and then with increasing tempo. She didn't realize that

a smile was slowly spreading across her face.

A human body hurled from the ninety-fourth floor takes a sickeningly long time to reach the ground. Reginald X.S. Baggage III's body struck the sidewalk with an outstanding *whump!* buckling and shattering the cement as though it were made of harder stuff. The curious crowd was swiftly cordoned off by the police.

At the same time this was happening, Melvin Fishminder was cursing and opening the door to his luxury hotel suite, to find a pair of detectives and their flashing badges. The detectives did not look like the sort of individuals you had a good time *with*. They showed Fishminder something else: "A warrant for your arrest."

Fishminder was properly chagrined. "My arrest? On what charges?" Inside however, he had the unpleasant feeling that he would not be enjoying the days and years to come after all.

"Fraud and misrepresentation," the one on the left said. The one on the right gave a vicious grin. "You really shouldn't have tried to buy that island Mr. Fishminder," he said: "You really shouldn't have."

"B—but—"

"The Mercedes will have to be returned too, I'm afraid. As for your other

debts," his eyes flicked about the expansive luxury behind Fishminder, in particular the half open bedroom door, "As you know, the People's Republic of Cuba has reinstituted the debtor's prison. The accommodations, I'm afraid to say, are probably not quite what you are accustomed to."

"If you will please come with us, Mr. Fishminder. . . ."

As Fishminder was being led away, Norman Roddery was also departing from his meeting with Senator Barnacle. As soon as he got back to his office, he called his entire staff in, opened a bottle of Chivas Regal, and started filling plastic cups generously. "Ladies and gentlemen," he said, "I give you—Project Starshield!"

There was some confusion, but by and large the first round of toasts went off fairly well. "You mean, Barnacle agreed to the funding?" someone asked the obvious anyway.

Roddery nodded, and poured some more. "Every last cent we wanted, and all overruns approved in advance." He banged the empty cup down on his desk, and plopped his slightly sloshed behind into the chair behind it. "What can I say? This calls for a celebration."

"Shouldn't we—ah—get to work?"

He shook his head. "Eat, drink, and be merry—for tomorrow we save the world!" ■

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● I don't know anything that mars good literature so much as too much truth.

Mark Twain

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## The Alternate View

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# NEUTRINO PHYSICS: CURIOUSER AND CURIOUSER

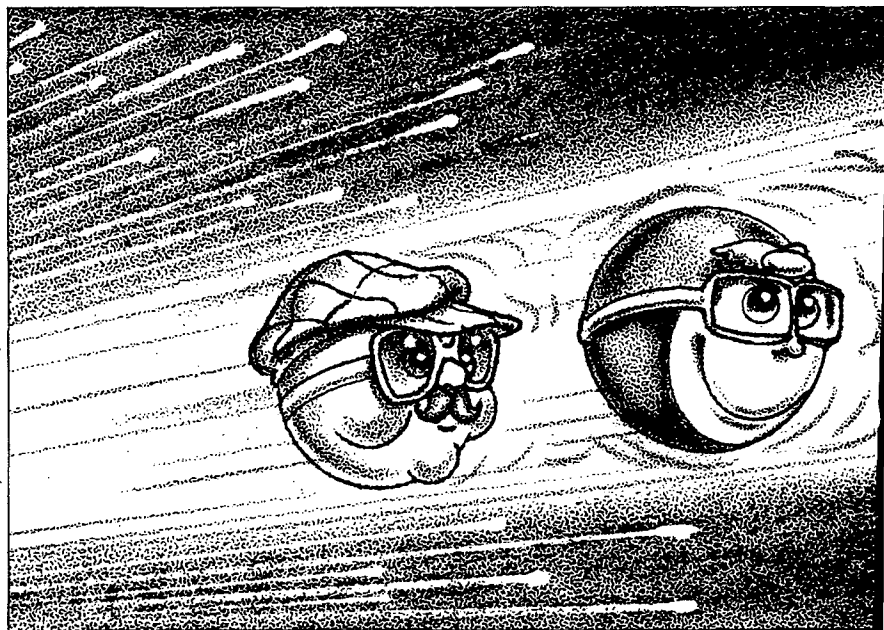
John G. Cramer

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New data on the nature of neutrinos has been appearing recently which is very strange indeed. Second generation solar

neutrino detectors and neutrino rest-mass measurements are both telling us that this elusive particle is even more peculiar than had been previously supposed.

Wolfgang Pauli first suggested the existence of what we now call the neutrino in order to preserve the law of conservation of energy. Previously, in 1911, James Chadwick had demonstrated that in the radioactive process called *beta decay* the emitted "beta particle" (now known to be an electron) was emitted with some random amount of its kinetic energy missing. Instead of the expected sharp spike of well-defined kinetic energy, a sample of many such emitted electrons showed that their kinetic energies were distributed over a broad bumplike distribution.



Following the discovery of the missing energy in beta decay many physicists, Niels Bohr among them, were ready to abandon the law of conservation of energy. But Pauli had a better idea: he guessed that the missing energy was being removed by a new particle that was invisible to Chadwick's detectors. We now know that he was correct.

Like the electron the neutrino spins on its axis like a tiny top, but unlike the electron it has no electric charge, little or no mass, it interacts only very weakly with matter, and it always travels at or near the speed of light. A neutrino can pass through light-years of lead without absorption or scattering.

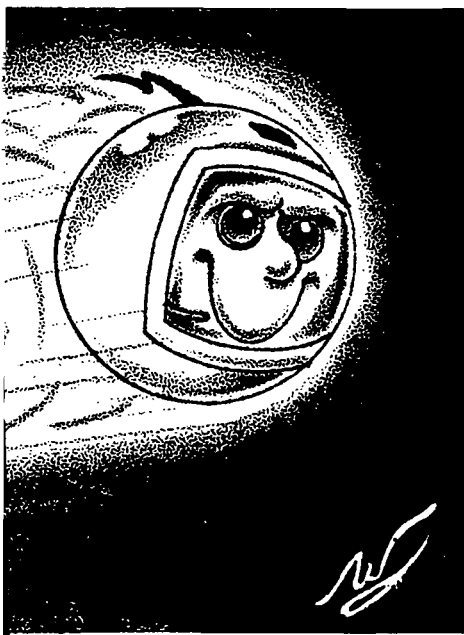
We now know that neutrinos come in several distinct varieties or "flavors." For each of the three charged lepton

flavors, electron (e), mu lepton ( $\mu$ ) and tau lepton ( $\tau$ ), there is corresponding neutrino flavor: the electron neutrino ( $\nu_e$ ), mu neutrino ( $\nu_\mu$ ), and tau neutrino ( $\nu_\tau$ ), and each flavor comes in matter and antimatter varieties.

Neutrinos also play an important role in astrophysics. In stars the fusion reactions are fueled by a medium that is essentially all protons. During the fusion process about half of the proton participants are converted into neutrons through weak interaction processes that involve neutrinos. A proton in some nucleus is transformed to a neutron, and at the same time a positron (anti-matter electron) and a neutrino are emitted and share the available energy. The neutrinos produced in such fusion reactions exit the star at the speed of light, carrying their share of the energy away with them.

The result is that all stars are bright sources of energetic neutrinos. About 610 trillion neutrinos produced about 8.3 minutes ago in fusion reactions at the center of our Sun are passing through your body in the second it takes to read this line. If it is night outside as you read this, the solar neutrinos are passing through the Earth to reach you. There are so many neutrinos streaming in our direction from the Sun that it is possible to detect them, even though the chances of detecting any particular neutrino are extremely small.

The first successful experiment to detect neutrinos from the Sun was mounted in 1968 in the Homestake gold mine in Lead, South Dakota by Ray Davis and his group from Brookhaven National Laboratory. This experiment, conducted 850 feet below ground level



in a 100,000 gallon tank filled with perchloro-ethylene cleaning solvent, has been in continuous operation for well over two decades and has produced a famous result. Only about  $\frac{1}{3}$  of the expected number of solar neutrinos are detected. Either the Sun is producing only  $\frac{1}{3}$  of the neutrinos that it should, or else the Homestake detector is somehow missing  $\frac{2}{3}$  of them. This neutrino deficiency was later confirmed by the Kamiokande II detector in Japan which, although it operates on a different principle, is sensitive to neutrinos in about the same energy range as the Homestake detector.

This puzzling deficiency of solar neutrinos, usually referred to as "the solar neutrino problem," has prompted a second generation of solar neutrino experiments. The first second generation experiment to produce results is SAGE, an acronym for the "Soviet-American Gallium Experiment." The experiment was initiated as a joint venture, with the Soviet scientists providing the deep underground site and about \$25 million worth of gallium, while the Americans provided the computers, detection electronics, and other hardware. The breakup of the Soviet Union has created a problem of nomenclature for the SAGE experiment, which is still in progress. The experiment is located within the territorial boundaries of Russia, and so it has been suggested that perhaps the acronym should be changed to "RAGE."

In the SAGE detection system a large quantity of gallium (element 31) is purified and held in underground tanks, waiting for solar neutrinos to transmute the gallium-71 isotope in the tanks to

radioactive germanium-71, which has a half life of 11.4 days. A chemical procedure separates the few radioactive germanium atoms from the gallium and transports them to a sensitive detector where their decays are counted.

If the results of the Homestake solar neutrino experiment were puzzling, the SAGE results are shocking: in over a year of counting, the net number of solar neutrinos they have detected, after subtraction of a small background, is zero. In an operating period during which hundreds of neutrinos should have been detected, none are counted.

This null result from SAGE is very difficult to explain. The system is supposed to detect neutrinos in a lower range of energies that are not accessible for the Homestake and Kamiokande II detectors. The strong implication of the two results is that there is not only a suppression of solar neutrinos, but that it is greater at lower energies than at high.

I will not, because of space limitations, discuss in detail theories that seek to explain these observations. The most plausible explanations use the concept of "neutrino oscillations," in which electron neutrinos are converted into mu neutrinos or tau neutrinos in flight, neutrino flavors that would be unable to transmute gallium to germanium in the SAGE detector.

Other second generation solar neutrino detectors in Italy and Canada are about to go into operation. We can expect new data from these experiments which should provide new insights on the solar neutrino problem.

An even more puzzling result seems

to be coming from several recent attempts to measure the rest mass of the electron neutrino. Why do the three neutrino species, unlike their charged lepton brothers and their quark cousins, have rest masses that are nearly (or exactly) zero? The standard model of particle physics is silent on this question. Unlike the photon, which must have zero mass because it is the mediating particle of the infinite-range electromagnetic force, there is no fundamental reason why neutrinos should be massless. They just *are*, as nearly as we can tell from measurement.

The best technique for measuring the neutrino rest mass does so indirectly by examining the energy spectrum of electrons produced in a low-energy nuclear beta decay. The "end-point" or region of the electron energy spectrum where the highest energy electrons are found is most sensitive to the mass of the e-neutrino (or e-anti-neutrino, which should have identical mass). If the neutrino has zero mass, the distribution near the end-point smoothly merges into the baseline. But if the neutrino has a small mass, the distribution at the end-point is chopped off early, producing a "nose" with an abrupt edge at the end of the electron energy distribution.

Measurements performed in this way have indicated that the rest mass-energy of the electron neutrino must be less than about 15 electron-volts. A number of second-generation experiments have recently been initiated to improve this limit by high-precision measurements of the end-point region of the beta decay of *tritium*, the mass-3 isotope of hydrogen, which because of its 18.6 keV transition energy is the lowest energy beta

decay known. The very low energy of the transition enhances the "nose" effect produced by the neutrino mass at the end-point and makes for the most sensitive measurements.

It is not widely appreciated that the end-point technique does not actually measure the mass of the neutrino. Because of the way that the neutrino mass affects the electron energy spectrum, the measured quantity is the *square* of the neutrino mass.

And this is where the interesting, although statistically shaky, results appear: of the six most recent experimental determinations of neutrino mass, all have given *negative* values of the mass-squared to within the statistics of the measurements. The experimental observation is that in the vicinity of the end point the yield of electrons lies *above* the zero-mass line, while for neutrinos with non-zero real mass, the electron yield should lie below this line. The measured mass-squared values are negative to an accuracy of several standard deviations in the most recent of these experiments.

These experimenters have been strangely quiet about mass-squared measurements with negative values. If the results had been positive by the same amount, the literature would be filled with claims that a non-zero value for the neutrino mass had been established. But a negative mass-squared is not something that can be easily publicized.

You obtain the measured mass value from a mass-squared measurement by taking the square root of the measured value. However, the square root of a negative number is an *imaginary* num-

ber. Thus the measurements could, in principle, be taken as an indication that the electron neutrino has an *imaginary mass*.

What are the physical implications of a particle with an imaginary rest mass? The late Gerald Feinberg of Columbia University has suggested hypothetical imaginary-mass particles which he has christened "tachyons." Tachyons are particles that *always* travel at velocities greater than the speed of light. Instead of speeding up when they are given more kinetic energy, they slow down so that their speed moves closer to the velocity of light from the high side as they become more energetic. Feinberg argued that since there are no physical laws forbidding the existence of tachyons, they may well exist and should be looked for. This has prompted a number of experimental searches for tachyons which, up to now, have produced no convincing evidence for their existence.

Some theoretical support for the existence of tachyons, however, has come from superstring theories. These "theories of everything" can predict the masses and other properties of fundamental particles. It has been found that some superstring theories predict a family of particles with a lowest-mass member that is "tachyonic," in that it has a negative mass-squared. I should add that such predictions normally lead to the rejection of the theory as "unphysical."

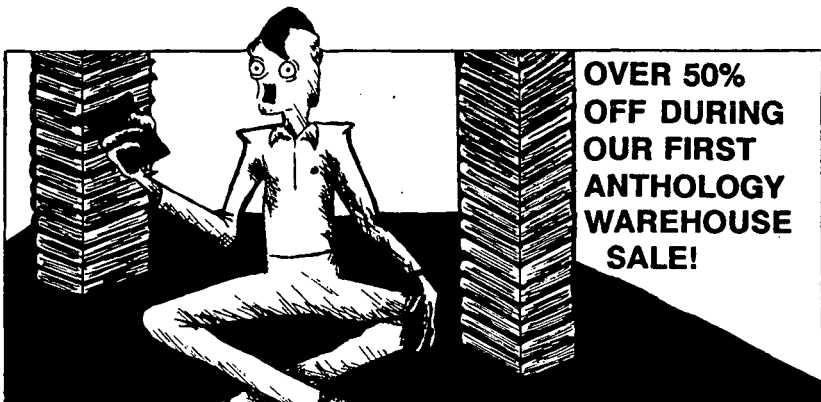
So, are neutrinos tachyons? Probably not. It is far more likely that the negative values found in the neutrino mass-squared measurements originate in some unsuspected experimental effect. Nevertheless, it is interesting to con-

template the possibility that the electron neutrino is a tachyon and to ask whether it is possible in the light of available data.

Supernova 1987A, for example, might be taken as a "test bed" for the tachyonic neutrino hypothesis because both the light and the neutrinos from the explosion had to cover 160,000 light-years to travel from the Large Magellanic Cloud to our detectors on Earth. We could view SN-1987A as a 160,000-year race between photons and neutrinos, with the fastest particles reaching the finish line first.

In fact, the neutrinos were observed to arrive 18 hours *before* the photons. However, this is attributed to stellar dynamics rather than FTL neutrinos. The neutrinos can leave the exploding star at once, while the photons must wait until the explosive shock wave travels from the core of the collapsing star to its surface. The more important fact is that there was a 12 second time spread between the arrival of the first detected neutrinos and the last, and the apparent grouping of the arriving neutrinos in "clumps" (possibly the result of poor statistics). This could be (but has not yet been) used to place an upper limit on how "tachyonic" the electron neutrino could be.

And so, in summary, the neutrino mysteries continue. Is the electron neutrino a tachyon? Does it change its flavor in transit from the Sun to the Earth? Watch this column for future late-breaking developments in neutrino physics. The only thing that is clear at the moment is that we do not have the final word on this most peculiar and enigmatic of fundamental particles. ■



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# CHRYSALIS

Alexis Glynn Latner



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To see the real  
importance of a  
major experiment,  
you may have to  
look far beyond it. . . .

*Brock Steadman*

Thin red clouds fringed the southern edge of the early sky, shreds of pollution that had drifted from sources hundreds of miles away. Such clouds promised yet another hot dry day Outside. Mark Willson glared at them through the glass and gray lattice of the dome, then left the observation deck and went to the mess hall, two levels down.

Will Diaz was in the mess hall having breakfast. Mark took a seat at the table next to the chief engineer. "Did you look out at the sky?" Mark asked.

"What was it?"

"Herring sky."

Will groaned. Then he asked Cookie for a second cup of coffee. The ration was one cup per day, but she poured him another without comment. Breakfast was eggs scrambled with diced prickly pear cactus, hot sauce, and cornbread. Mark asked Cookie for peppermint tea instead of coffee this morning.

"What's on school for you today?" Will asked the boy, between forkfuls of egg.

"Saturn's great white storm," Mark answered.

Will flashed a grin. "Now that's cool weather for you." Over his coffee cup he added, "I saw the one in '50, from outsystem. That was when I was serving on the *Jovian Explorer*. Saturn looked—"

Aggie Robbins, the agronomist, chose that moment to interrupt, leaning over Mark's shoulder to address Will. "My tomato plants can't take another one hundred degree high," said Aggie, flatly.

"I've got worn-out, broken-down, duct-taped-together air conditioners," the chief engineer growled back. "So

sit on your tomatoes."

"Well, I hope we all like eggplant. That may be all that bears through *this* summer." She departed in a huff.

"Cluck, cluck, old hen," Will muttered. Pushing his plate away, Will left to go to the air conditioning plant.

Mark spent the morning on Netschool. Today's meteorology seminar was based at Cornell University. With classmates from all over the inner Solar System, Mark studied the equations that described the great white ammonia storm on Saturn. Mark wished that the seminar had been scheduled for this afternoon, not this morning. Too important to miss, it was making him put off his chores until the heat of the day.

After school, Mark reluctantly left the relatively cool classroom in the Mission Control Center. The Center's screen door slammed behind him. He scuffed along the well-worn path that marked the ecological boundary between the glass-domed veldt and the sea, the horizon of which was a curtain of glass a hundred yards away.

The wave machine hidden in the water made the little sea surge against its little shore. Mark remembered that there was a dream that he often had about running across mountains and valleys, all the way to a real sea. Maybe it was the prehistoric sea that had once covered this land. It had no name in the dream, just vastness and blueness and cool wind. Wind, he thought, must be like standing in front of the air conditioning vents, only wider.

Mark sighed. While he stood here daydreaming, the day was getting hotter. And he had to get today's chores,

formally known as the individual work list, done because there would be more to do tomorrow. The path took Mark to Mander Creek. He waded across. The water felt pleasantly tepid to his bare feet.

People getting their chores done had been wading back and forth all morning and splashing water from the creek onto the path. Mark found butterflies on the wet dirt, two kinds of Blue and one Sulphur. Slowly and quietly Mark crouched beside them. He rubbed a finger across his sweaty brow, then extended the finger toward the nearest Blue. The butterfly obligingly climbed onto Mark's finger. When its tickly little hind feet touched his skin, the butterfly discovered that Mark tasted like the salt it craved to supplement its nectar diet. The butterfly uncurled the long coil of its proboscis to sip the perspiration. With a finger of his other hand Mark collected the other Blue the same way. Then he transferred the first one to his equally sweaty and tasty nose and crossed his eyes to look at it. It flexed its wings, a brown blur with a lavender sheen.

Butterflies really liked the endless bright and humid days. Mark didn't, but he had work to do. He gently placed the butterflies on a spot of nice mud.

A glass pyramid six stories high housed the rain forest. It included a miniature mountain with a cascading waterfall that was the source of Mander Creek. Mark felt rather than heard the water pumps, a subsonic presence, as he skirted the mountain. The rain forest floor was flowery green shadows heavily laced with organic smells: cloying in this heat and humidity. Mark passed a

few other Ecos. They nodded. He nodded. You didn't chat at people in the wilderness biomes, because they might want the solitude that was not available in the Domicile or on team assignments.

At the end of the rain forest, the glass pyramid slanted down to the ground, thwarting the trees. There the Ecos had their garden: papaya, coffee, and huge stalky banana trees that pressed against the glass; lesser plants—the chilies and tomatoes, corn with beans twining up the stalks, cotton plants crowned with white bolls, and millet—where the glass met the ground.

The millet was mixed in with numerous green blades that were not millet. Grasses and little trees from all over the Ecosphere had made their way here. Mark knelt to pluck the aliens one by one. He sorted them by species, putting the sprigs into a sorting tray. He would return each green sliver to its proper biome. That was the problem with compressing a world into eighteen acres: most plants and animals could travel that far. Chickens from the agricultural biome had been found nesting everywhere from the rain forest to the Mission Control Center. Where the chickens, potbellied pigs, water lines, and air conditioning vents went, plant seeds followed. Keeping all of the biota sorted out took incessant work. *Homo Sapiens* occupied the entire Ecosphere in the ecological niche of predator *cum* caretaker.

His sweat attracted gnats and small flies. He thought about Will Diaz in the air conditioning plant, where it was hotter than this, with grease and grime to get on a person's skin. As daily temperatures soared in the desert Outside, the

air Inside expanded as it heated up. The hot air would have blown out the sealed glass walls if not for the variable volume chambers, gigantic bellows designed to soak up the expanded hot air—Lung One and Lung Two. “The lungs are mechanically simple,” Will had told Mark a few days ago. “No danger of ‘em breaking down. But we need AC too. One of the units is on its last legs, and right now I can’t take it out of service long enough to rebuild it again!” Will had added, “After I die and they compost my body, don’t look for my soul in purgatory. I’ve done my time in the AC plant in Ecosphere!”

Mark had been pulling little green sprouts all summer, which was less purgatorial than Will’s job, but he was sick of sprouts, and now he was getting tired. He looked out through the glass, across the desert and toward the blunt spine of the Davis Mountains.

Green things die in the desert and in the cities, Mark’s mother always said, and there’s not much Outside that isn’t one or the other. The Computer Net brought a seemingly endless supply of images of pretty green cities and parks, elsewhere on Earth. “Edited!” his mother said vehemently. “They crop out the pollution and the ugliness. And then they fill up the blanks with artificial prettiness made by the computers!”

Mother had walked into Ecosphere twenty years ago and let the airlock seal behind her. She and the others were scientists, participants in the largest and longest lab in biospherics the world had ever seen. Mother and Will and Aggie and Cookie and thirty of their colleagues. They had stayed in Ecosphere, tending it and learning from it for two

decades. And now they understood biospherics pretty well. They, with the planetary scientists, meteorologists who had studied Venus and Titan and Saturn, and the restoration ecologists, knew enough to save the world. But it hadn’t made a decisive difference in civilization’s practices.

Even around the Ecosphere, the Ecos had seen the landscape around Ecosphere get drier and grayer over the years while they labored Inside. The red herring skies started ten years ago. In a kind of response to the evils Outside, the Ecos had let the airlock vestibule turn into the Junkyard, full of scraps and old parts and a few nesting hens.

Mark shivered. The landscape on the other side of the glass was no computer generation, it was real, and, in the hot midday, midsummer light, fiercely desolate and pale. Smudges of moving dust—dust devils—stalked the gray hills. Suddenly Mark felt sick and weirdly cold. Maybe it was the heat, maybe even heatstroke coming on. Wiping the sweat out of his eyes, Mark backed up into the spindly shade of a coffee tree and sat down to rest.

A butterfly flew by on huge wings shimmering like twin scraps of blue silk. Mark knew the Latin names for every butterfly species in Ecosphere, and all of the sexual dimorphisms, and this one was his favorite: a male *Morpho Amathonte*.

But not even the *Morpho* made Mark feel better today. Its home rain forests, shredded by logging operations in the previous century, were dying now even as the trees tried to propagate northward to escape the desertification that pressed upon them from the south; but there

were huge polluted cities blocking the way north of the Central American rain forests. Morpho was a refugee. The butterfly was blissfully unaware of its situation, only knowing its duty to patrol its territory and at intervals revisit the dun female who rested under a branch nearby. Going on about its butterfly business, Morpho went away, its blazing blue instantly extinguished when it flapped into the deep shadow of the forest.

Mark went back to Eco business, the millet. Outside, waves of heat rippled over the tawny desert, like a sea of visible high temperature.

Something creaked over Mark's head. It wasn't a croak, a tree frog. It was a *creak*. High up on the glass wall of the pyramid. The wall creaked again. Mark jumped up. He frowned at the lattice framework and the glass up there. It was the south wall, the one that had been subject to the most heat stress for decades. Once white, the lattice had been weathered gray, scoured by sandy winds, etched by acid rains. Maybe the framework, like Will's air conditioning machinery, had become brittle, or even misaligned. Squinting, Mark could imagine that the lattice was crooked, slightly imperfect triangles around stressed panes of glass, and how the frames were expanding in the ferocious heat of this day.

With a third creak, a jagged and branching crack appeared in a section of glass high up on the wall of the pyramid. Stunned, Mark stared. The hot expanded air inside Ecosphere wanted out. The air pushed pieces of glass out into the Outside. The rush of outgassing atmosphere stirred the banana leaves

near the breach. Shards of glass trickled down the outside of the pyramid wall, like raindrops, but brighter.

Mark screamed for help.

There was a makeshift scaffold in place, made of pipes and parts snatched out of the machine room under the mountain. Will Diaz's assistant, Joya, climbed up the scaffold armed with a big container of glue. "Give me the plexi!" she ordered.

The Ecos on the ground handed up the big sheet of plexiglass from the Junkyard.

Mark remembered things that the out-planeters at Netschool had told him. How the death of airlessness or, on Titan, poisonous air hovered over their sealed domes, and what happened if an accident or an act of sabotage cracked a dome, the panic, the quick action when the dome cracked; the slim hope of averting total disaster. Here nobody would die. The disaster would be the end of a twenty-year scientific experiment and of Mark's world.

"Damn!" Joya struggled with the plexi, which was too heavy for her to lift easily.

Will Diaz grabbed Mark's shoulder. "Go up there and help her!" Will boosted him onto the scaffold, and he scrambled up. It would not hold much more weight than his and Joya's and that of the plexiglass—if it did as much. The scaffolding quivered under them. The Ecos on the ground made ready to catch whomever or whatever fell.

Joya slathered glue on the plexiglass. The pyramid glass slanted over their heads, so they were in an awkward position as they tried to place the plexi up

against it. Worse, the lattice was in their way, interior struts making it impossible to position the piece of plexiglass. Every time Mark or Joya shifted their feet, the rickety scaffold shook.

"Put it outside!" Will Diaz ordered in a loud voice.

"What do you mean?" Joya asked over her shoulder.

"Tilt the plexi through the hole long-ways, then it'll lie on the outside!"

"It will slip off the pyramid!" she yelled back at him.

"Not if it's propped on the bar!"

Right under the broken pane, the pyramid's framework wasn't flush with the glass. A main structural bar was there and it protruded, making a small ledge, wide enough to prop the plexiglass on. "We could too easily drop it!" Joya objected.

Captain Fleming arrived at a run, announcing, "We're not contaminated yet, the positive pressure's kept outside air from coming in! If we can seal this up, people, we're still in business!"

"Fix it!" Will Diaz bellowed up the scaffold.

Mark grabbed a banana tree that was jammed up against the glass, and with its help he started to lever himself through the jagged hole in the glass. Air still escaping from Ecosphere drafted past him.

"What are you *doing*?" Joya hissed.

"If you're in and I'm out," he answered, "we can stand the plexi on the bar. Then I'll come back in and we slide the plexi over the hole."

"*Don't!*"

But Mark was already out. A yell went up from the Ecos on the ground, Will Diaz audible above the rest of

them. "Don't fall!!!"

Mark found a toehold on the ledge. There was a wind out here. He felt it blow on him and he breathed it. If this had been Titan, Mark would have been breathing poison. But the wind descended from the oxygen blue sky of Earth. Dry, it cooled his flushed skin. He swiveled and leaned against the pyramid, his hip resting against the vertical frame between the broken glass section and the unbroken one next to it.

In the west, the sun was setting in a butter-golden brightness such as Mark had never seen in his life. He made the mistake of glancing directly at the solar disc. It left one small intense green spot of afterimage on his retinas. Dazzled, he groped for the end of the plexiglass that Joya handed him, and they started to maneuver it out.

The frame he was leaning on produced a grinding sound. Alarmed, Mark blinked down to the ground. A twenty-foot drop, but not vertical, rather a glass slide. "Joya, more of the glass up here is loosening! Maintenance had better go over all the seals."

"Tell Will later. Here!"

He had most of the weight and most of the control of the plexiglass now and struggled to stand it on the bar. But the wind exerted a force on the plexi that Mark hadn't expected. Suddenly he realized that he was either going to lose the plexi, or his balance, or both. Mark threw his weight against the plexi, pushing it up where it needed to be against the breach in the glass. Then Mark fell, skidding down the glass wall to land on dirt and cactus. He rolled off the cactus. Inside, the Ecos were screaming and waving, all except Will. Will was point-

ing away from the rest of Ecosphere, emphatically gesturing toward the east.

Mark turned his head that way.

The sky unfurled over his head, vast and vivid and intolerable.

Terrified, Mark ran. He stumbled on the loose stones of the ground and kept going, running his breath out, until he dimly realized that the sky had mostly gone away. Wheezing and shaking, he collapsed. He was in the Southways gulch and out of sight of Ecosphere.

Mark's heart fluttered. He was Outside. *Outside for good.* He could not go back into Ecosphere, could not ask them to open the airlock, break the seal, admit him and the dust and microbes he had picked up, particulate Outsideness clinging to him. Shuddering, he thought he might be sick. Then he stopped himself. Not only was he out, he was out in a cruel desert, and he thought that vomiting would make him lose body water. He would dry up like a fish out of water and die.

Mark licked his lips, which felt parched already. He was thirsty. Mander Creek with its lukewarm water would have been wonderful, right now. It would have felt so good to drink and to bathe his feet. They hurt. His soles were calloused because he never wore shoes at home, but the wild desert surface was rougher and hotter than any ground in Ecosphere. He huddled on the warm dirt in the gulch, glad for the stony walls that let him see not too much of the terrible wide open sky.

Something pricked at the palm of his hand, so he moved it. There were scrubby grasses poking up out of dry, stony, but living dirt. Grasses growing not because someone had planted and

tended them, but because it was the way of grass in nature to grow in open places. Mother was wrong. Things did live in the desert. Unfortunately Mark Willson was not a xerophyte. He would die in the desert.

Will had been pointing east, the direction of Mount Locke, with broad emphatic gestures. Suddenly Mark understood why. He limped toward the end of the gulch to peer out. There was a road. It looked terrifyingly endless and empty. The colors of the sky overhead—blue to red—were more vivid than he had known, much brighter than the herring sky he had seen this morning. He realized that the glass of Ecosphere had been dirty. Over him now was the untrammelled and plain truth of sky, and it intimidated him. He craved retreat, staying, hiding in the gulch. But there was no water there.

A shaggy bird with a long tail ran out onto the road. It was one of the Outside birds known as roadrunners; Will called them by a Spanish name, *paisano*. Will used to call Mark "Paisano" when he was a little boy, so small that Ecosphere seemed enormous, because he had loved to run all over the place. Braking to a sudden halt, the roadrunner twitched its long tail and considered Mark with one eye; then it dashed off down the road, disappearing around a curve.

In the shades of sunset, Mark painfully stepped onto the road, old, with cracked asphalt. It was too hot to stand still on. He walked fast, the same way the roadrunner had gone. Behind him the road began at Fort Davis. On the other end of the road, east, lay the top of Mount Locke and the Ecosphere's

nearest neighbors. He even thought he saw the domes on the mountaintop, turned into pink pearls by the sunset. The pink pearls were still a long way away, and a long way up from here. They looked too close to the awesome sky.

He tried imagining that glass was still up above him—like the wide span over the veldt and ocean biomes. Higher, cleaner but still sheltering glass. Suddenly he realized that it was true. The Earth's atmosphere was like greenhouse glass, and not all that clean, either: sunsets and sunrises were red because of pollution in the air.

The reddened sun set. The glass of air turned transparent and planets and the brightest stars appeared in the sky above Mount Locke. A cool wind cut through the loose homespun fabric of his clothes. His feet hurt. So did his backside, where he had landed in the cactus. So did the cut on his right forearm, a long curving scratch where the broken glass of the pyramid had grazed him in getting out. Mark forced his physical discomfort out of his mind. Life in Ecosphere had made him good at that. What had to be done had to be done. He trudged on. At least the road bed was mostly flat and easy on his feet, warm, though slightly sticky. Or else the stickiness was blood on his feet.

From the direction of Mount Locke, he heard a mechanical sound, correlated it with a cloud of dust. A car sped down the winding road toward him. Surprised, Mark stood still. Then it occurred to him to get out of the way, and he jumped off the road just as the car's headlights flashed over him. But the car braked. The driver

leaned out. "Are you Mark Willson? From Ecosphere?"

Mark had never met a stranger in person before. And he, barefoot, was wearing Ecosphere homespun. He must be either somebody from Ecosphere or a revenant peasant from the 13th century. Mark nodded warily.

"I'm Edwin Ferris from the Observatory. Your Captain Fleming called us, said you'd been shut out by accident, and could we try to find you? He asked us to take you in for the night. Definitely! We'll be home in a jiffy. Hop in!"

From the Net, Mark knew about cars. Mark was pretty sure that this one was an electric-powered, all-terrain vehicle, a Sand Rover. But he had never traveled in a car or any other mechanical conveyance. Gingerly he put himself in the seat indicated. "Th-th-thank you very much." His teeth chattered.

Edwin Ferris turned the car around. The motion made Mark clutch at the seat. "Had to charge up first, because I just got back from a supply run to Marfa. I'll turn on the heater," said Ferris.

The first hill road curve took Mark by surprise, centrifugal force nearly throwing him into Ed Ferris's lap. Ferris laughed. "You don't have to compliment my driving. Nobody else does! Just buckle up the belt." Abruptly, Ferris sobered. "Your captain said you've never been out of Ecosphere. Makes sense if it's been sealed for twenty years. So you've never been in a car before, have you?" Ferris slowed down. "I don't want to traumatize you!"

Ferris had wispy gray hair. He looked

older than anyone in Ecosphere. But he sounded like any of the old men, professors, scientists, and parents of Ecos, that Mark had met on the Net. Mark asked, "Are you an ast—tronomer, sir?" This time he suppressed all but one chatter of the teeth.

"Oh, we do some astronomy, Earth-Moon distance measurements to the centimeter—it changes, you know—and parallaxes for the nearest stars. That's really important. We have to know exactly where and how far away they are, before we send starships!

"But serious astronomy is done in space these days. We're just a teaching facility. And a meeting ground for astrophiles—people who love to look at the stars. Most professional astronomers don't, you know, look at the stars with their eyes. Machines scan photos to find asteroids and comets. But at MacDonald Observatory you can still see the stars for yourself."

"Can you see the storm on Saturn?"

Edwin Ferris beamed toward his passenger. "If you're interested, I can show you that tonight! Even from Earth, it's quite a sight." In his enthusiasm, Ferris speeded up. Then slowed down again, contritely saying, "Sorry!"

Warmth flowed onto Mark's feet. His shivering subsided. He watched the rock layers of a road cut seeming to flow by, and twisted cacti on the dusky hillsides that arced in and out of his sight. The car was going uphill in looping curves. He felt like a dreamer again, running with effortless grand gestures over a strange landscape, fearfully exhilarated. He could have explained that feeling to an Eco, but not to a stranger, though this one seemed friendly and

good. He said, "I like riding in your car."

A hurricane saved Ecosphere. One of this century's monster storms, the hurricane had blasted the Gulf coast, but by the time it got to the Davis Mountains it was all rain. Cooling the land and the air, the last remnants of the storm took the load off Will's ruined air conditioning unit, for a while.

The land was faintly blooming with cactus brought to life by the rains soaking through the hillside. Mark could see the blooms as faint colors in the cold gray dusk before dawn, colors blurred by the speed of the Sand Rover as it zoomed down the flank of Mount Locke.

The last two weeks seemed like the same kind of variegated and thorny blur, now, as he thought back over living at the Observatory. As promised, he had been taken in. Ed had shown Mark Saturn, with its blaze of white; and star fields, the glories and the depth of the stars. The nearest stars parallaxed as the Earth orbited; those were stars near enough for starships from Earth to reach, said Ed. To Ed's surprise and delight, Mark had voluntarily and quickly begun to learn how to find stars by celestial coordinates, to point the telescopes and operate the other instruments.

Helping Ed had been interesting and far easier than interacting with the rest of the staff at the Observatory. He felt as though he had been blundering into social thorns the whole time. Especially when it came to the women—an astronomer and a technician. They made him nervous. And his nervousness made

him quiet and skittish around them. Once, soon after he came to the Observatory, Mark had heard the women, who had underestimated his hearing, agree that he was socially retarded. That overheard remark had hurt. Remembering it still hurt.

"Your Ecos must be real morning lovers," Ed grumbled. Ed hated sunup in any other context than as an astronomer's bedtime.

"Contractors are diurnal too," said Mark.

"But why do you have to get there before the contractors do much more than open a tool bag?"

"I'm not sure," Mark answered. "Will said he wanted me to look over the contractors' shoulders while they do the work. It was the captain who asked me to come at 0600 hours. I guess he wants to brief me."

Or, he thought, drum me out officially, in person, over the intercommunication system off the Net. Captain Fleming must have figured out that Mark didn't fall off the pyramid entirely by accident. Falling had been accidental—the wind's fault—but Mark had not had to put himself out there, in imminent danger of just that. Deep down, he had really wanted out, just like the hot air, just like the banana trees crammed against the glass walls. He remembered the old running dream. It had been a symptom of his agoraphilia. The captain must know that. The captain of Ecosphere had always known everything. Mark's stomach knotted around the bagel and chocolate milk that Ed had given him for breakfast.

Ed, sleepy, sighed deeply. He slowed the Sand Rover to look for the turnoff

to Ecosphere. "Twenty years and they still want to keep the experiment going and stay in? All of them?"

"There's a girl about my age. Her name is Nessie and her dad is the physician, Doctor Tu. I think she really wants to go to medical school. For the grown-ups, though, it's like the Ecosphere is the whole world. For scientists, like my mother, there's so much to learn that all they want to do is stay there and keep the experiment going."

He had talked to his mother on the Net. She was happy that he was safe. And something else: she had seemed relieved. She had never really wanted to be a mother. She had given birth to Mark for the sake of the biological model which postulated a certain number of children. That was the kind of secret that wasn't much of a secret in the confines of Ecosphere. On the Net, Mother had talked to him like an adult, and enthusiastically filled him in on the operations of Ecosphere in his absence.

"What about your da—Diaz?"

"He's older than most of them. Almost sixty, so he had half a life outside of there. He's happy."

Ed found the turn and drove into the gulch. "But you weren't."

Mark gave him a shocked look.

"Wanderlust," said Ed. "Characteristic of the young males of the species. And sometimes of the old."

The track was rough. Ed had to hold the Sand Rover's speed down to not much faster than Mark had run, two weeks ago. He had shoes now, machine-made shirt and pants, and a sweater, loaned out of the kindness and the pity of the people at the Observatory. Mark desperately wanted to ask

Ed if he could make a life for himself in the outside world. The question tied itself into a tangle of hope and fear, unaskable. Ed wasn't a stranger now, really. But Mark was.

A twisting turn, clambering over a rise, and the end of the gulch revealed it a quarter of a mile away, the Ecosphere: the barrel vaults of the Ag biomes, the long glass hall of wilderness, and the rainforest under the high tower of glass on the east end. Inside lights were already on—to give the Ecos extra day while it was still cool enough to work. The lights silhouetted the twenty years' worth of rainforest that pressed against the pyramid of glass. Ed whistled softly. "There seem to be a lot of trees packed in there now."

"Part of the plan was to grow a rain forest," answered Mark. To his eyes, Ecosphere was astonishingly small and frail and full. "It looks like a chrysalis," Mark said. He had never thought so when he had lived Inside and it had seemed like a palace. "Have you ever seen one, Ed? A chrysalis that's ready to break open, and it's transparent, so you can see the butterfly inside—?"

"On televi—," Ed grunted. He said, "Contractors aren't even here yet! Well, go report to your captain. I'll just stay here and catch forty winks."

Mark got out of the car, where Ed had parked in an ancient and barely discernible parking lot, and went to the old terminal under its weather hood. Mark stared at the dusty keyboard. He had talked to the captain on the Net, to his mother, to Will, and to half of the other people in Ecosphere since he left. This was different. Making mistakes and corrections, Mark typed in the captain's

private number. Maybe the intercom wouldn't work. But it did.

Fleming answered at once. "Saw you coming." Behind him, Mark recognized the walls of Fleming's office in the Mission Control Center. "Mark, it's too bad you're out. But it turned out to have been the best thing that could have happened. You are responsible for the Genesis Foundation saving Ecosphere!"

Mark let out a long, soft, invisible sigh.

From the Observatory Mark had called Ecosphere, and talked to Will Diaz, whose dark mood had been brightened by learning that Mark was safe. Ed Ferris had gravitated into the conversation. It had turned out that Ed remembered the long-ago *Jovian Explorer* mission quite clearly and was pleased to meet one of the former crew members. Learning of the mechanical catastrophe in Ecosphere, Ed suggested that the Ecos contact something called the Genesis Foundation; Ed was on the Board of Advisors. A day later Captain Fleming had been talking directly to the Genesis Foundation. And now the Foundation was going to replace Ecosphere's air conditioning units.

"Is that Ferris yonder?"

Mark had sighed out all of his breath, and struggled to get enough of it back to make an audible voice. "Yes, sir. He's resting. He usually works all night and goes to sleep at sunup."

Fleming laughed dryly. "He'll have his reward! The Foundation's executive director is coming. Janet Warren. Make sure you roust him in time to meet his heroine." Mark nodded. Captain Fleming continued, "You'll be Will's eyes

on the outside during the contract work—you already knew that. For me, you're my proxy. As such I want you to understand the whole picture. The consortium that built us in the first place is no longer viable. The universities have expressed a sudden lack of interest on the grounds that it's less than a perfect experiment in biospherics now. That means they can't spare the kind of money it would take to make the repairs we need.

"The government, meanwhile, has realized that biospherics is hard work, and they have elected to go with the kind of space habitats into which you throw a steady stream of resources to keep them going. But the Genesis Foundation is keenly interested in Ecosphere even as is, with mechanical damage and our blowout the other day. The ultimate goal of Genesis isn't pure biospheric isolation, but modules on an Earth-like but barren world. Terraforming modules." Fleming cleared his throat. "I think their shrinks are interested in us too. Why, I don't know."

Mark could guess why. The staff at the Observatory had been shocked to hear that the Ecosphere had a three-to-five male-female ratio. Only a couple of the astronomers nodded with tentative understanding when he explained the biological rationale. The others seemed scandalized that he had no full brothers or sisters but two-and-one-on-the-way half-siblings. The Observatory people seemed to think that the Ecosphere people had gone strange being physically isolated from the rest of the world for so many years. The Genesis Foundation probably wanted to know what to expect of human psychology in a small, sealed

and isolated terraforming station on an inhospitable world.

"Never mind. The important thing is saving Ecosphere! I gather that it may have been Warren's decision, personally. Her party will arrive by 0700 hours. That's *Dr.* Warren, mind you. I don't want her getting the idea that we're a bunch of beggar biologists in here. So try to tell her things about Ecosphere that'll impress her!"

"Yes, sir," Mark promised.

The captain gave him a little semi-salute, and signed off.

Strangely enough, instead of feeling better, Mark felt worse now. He wasn't sure that he was up to the job that the Captain had given him. Captain's proxy—to a powerful Outsider woman. Chilly nervousness crept down his spine, into his legs, making them ache.

Agitated, Mark had to move. He began to circle around the Ecosphere. Inside, Ecos were hard at work. They appeared as blurry, blank shapes behind the glass, which was colder than the humid air and heavily fogged. None of the Ecos Inside had rubbed a hole in the condensation to look out and see the new day.

Mark had talked to almost everyone on the Net. But he wanted them to look Outside and see him now. *He* had always looked out from the observation deck on the roof of the Domicile and from the ground-level borders of the glass, he had noticed things moving Outside, clouds and dust devils and tumbleweeds. But then maybe he had always been the only one interested in the Outside land.

His legs definitely ached. His throat felt scratchy. Maybe he was coming

down with something, he thought. Almost two weeks since he bolted from Ecosphere: just about time enough for the new germs he had met at the Observatory to incubate into a cold or the flu. And if he got sick, he wouldn't be where Doctor Tu could take care of him with a cool stethoscope and soothing words in Chinese. And he wouldn't get any of Cookie's chicken soup.

Mark craved the warmth and security, the familiarity of Inside. Tears oozed out of his eyes, drying quickly in the desert air.

He passed the desert biome, gentler and foggier than the continent's interior badlands out here. He paused by the agricultural biome. He recognized the skinny, bustling form of Aggie Robbins, the chief agronomist. Nearer to the glass stooped the bulky shape of Davy Annon, hard at work weeding. Davy was Aggie's right hand, better than most Ecos at the simple, manual work that Ecosphere required so much of, valued for his productivity and for his pleasant temperament too. But in the Outside world Davy would have been a pathetic misfit: he was mentally retarded.

Mark swallowed hard. His throat definitely hurt.

Kicking rocks, Mark cut across the bay between the Ag Biome and the rain forest. The bay traced the edge of the veldt, the thick pelt of the grassland visible Inside. Outside, a smattering of scrubbiest grasses fringed the glass, huddled against it like children outside a candy store window. Runoff during rains made the glass edge of Ecosphere more hospitable than the desert at large.

Mark located the plexi-patched glass

on the rain forest wall. Under the glass, there was a clump of prickly pear with some broken pads and stems—the cacti that he had landed in. Absently, Mark rubbed his backside, remembering how the pricklies had retaliated. These prickly pear looked stringier than the ones which flourished in the desert biome and had to be eaten back, turned, into *nopales* and pear jelly. Cookie would have thrown up her hands at these specimens and said, That's not coming through my kitchen, feed 'em to the chickens!

Yes, there was life in the lands outside of Ecosphere. But the world was in a great die-off. The future would belong to cacti, insects, and small weeds that traveled where great trees could not. Cactus and cockroaches and crabgrass would inherit the Earth.

In the cloudy green garden under the bevel of the pyramid, Mark distinguished a person, a girl. It took him a few moments to recognize Nessie picking papayas. Unnoticed—she paid no attention to the desert Outside either—he watched her. Smart and skinny and assertive ever since Mark could remember, Nessie was a year younger than he. Once, on the playground when they were small, she had slugged him with the result of knocking him flat. In the last couple of years the two of them had teamed up for Netgames, placing as high as fourth in Solar-System wide competitions.

The woman technician at the Observatory, Kalyn, had been surprised that Mark had never kissed a girl, receiving the information with a startled glance of her blue eyes and a gesture brushing her long blonde bangs back from her face.

But it made sense. Forty original Ecos from all over the Earth had been pleased to love and quarrel with each other and, in any event, have children. The population was now about fifty, a good match for the carrying capacity of Ecosphere. But fifty was too small a group to grow up in and marry someone. Fifty was a human natal band. The adults might as well have been his aunts and uncles. Nessie might as well have been his sister.

Through the glass, Mark realized that Nessie was not really skinny anymore. And she had another name, he remembered. Vanessa. Vanessa, the lithe shape, was making him feel very much like Kalyn did, even though Kalyn curved more dramatically. The difference in shape didn't matter as much as the similarity. Mark felt attracted, confused, and socially retarded.

He hurried the rest of the way around Ecosphere and turned back toward the car. Finally, over his shoulder, he saw two misty little kids Inside, stooped over the backwater of Mander Creek, probably intent on counting salamanders.

The contractors and Janet Warren would soon be here. Mark checked the clock. It had taken twenty minutes to walk around Ecosphere on the Outside. It took longer than that just to walk from MacDonald Observatory down to the mailbox on the main road!

The early sun gleamed golden highlights onto the vaults of Ecosphere. The morning was cloudless and the sun would not be mild for very long. Thanks to Will Diaz, he had a fair amount of melanin in his skin, but it was no match for the ultraviolet that streamed through

the Earth's ozone-depleted atmosphere. Mark sat down in the Sand Rover and reached for the sunblock stashed in the glove compartment.

Rumpled and sprawled in the front seat, Ed opened his eyes and said, "A chrysalis. Yeah, I've seen those things on nature specials on televid. Monarch butterflies, right? The ones that migrate so far. The caterpillar bundles itself into a chrysalis, and the chrysalis finally turns into a transparent thing with the butterfly's wings and legs and feelers packed inside. Then it breaks open and the butterfly crawls out limp as a wet dishrag, and it hangs onto a nice safe twig while its wings dry. More wing than you'd imagine could've fit into that tiny shell. I *have* seen monarchs, by the way, on goldenrod plants, years ago, when I used to have a place in the country outside of Austin. The wings look like orange and gold stained glass." Ed's face was flushed with enthusiasm, and with early sunlight. He waved his hand toward Ecosphere. "A chrysalis! The life of Earth, packed into a glass shell. Ready to break out and fly. To the stars."

Then Ed asked, "Is the captain going to let you back in?"

"Huh? No. Of course not," Mark answered.

"Did he say why not?"

No. He hadn't had to. *Outside is Outside*. "I've—for one thing, I encountered a lot of microorganisms since I got out, that might change the whole microflora of Ecosphere."

"I'm sure you encountered some of Kalyn's last Saturday night," Ed said mildly.

Mark felt his face flame with embar-

rassment under the sunblock.

After an afternoon of rain followed by cleared skies, the observatory staff had thrown a party. They called it a Star Party. With candy sweeter than Cookie's syrup corn balls, liquor stronger than Ecosphere homebrew, and music.

Mark had listened to the silence under the conversations at the party. There were almost none of the subtexts of tension, attraction, grudges and other unfinished business, the unspoken but perceptible dialogues under the audible ones, that he had been used to in Ecosphere. He felt lonelier yet freer here. Visiting the candies in the corners of the recreation room, Mark had felt a breeze coming in through the open window. Drier than the airs of Ecosphere, fresher than the drafts from the air conditioners, the wind intrigued him. He went outside onto the telescope plaza.

He still wasn't used to the vista under the plaza. It made his head spin and his adrenalin rush. Miles of low gray land, vast aridity, lay in the gloom of twilight. Nearer, the ragged crowns of lesser mountains than Locke glowed in the late sun. Unlike the barren plains, the mountains were flecked with green. Mount Locke itself harbored cacti and various bushes, and sloped into canyons with juniper trees and oaks. The mountain was a high island to which many species had retreated out of the desert drought. Locke was like Ecosphere, an oasis.

The wind smelled green. It reminded Mark of the smell of Ecosphere, though a paler green and more elusive. Mark had an urge to run with the wind across the mountain. But his feet, blistered,

bruised, and cut when he ran away from Ecosphere, had not completely healed.

To Mark's dismay, Kalyn had trailed him onto the plaza. She wanted to know how old he was.

Mark answered, "Sixteen."

"Oh, Then you're an under socialized overachiever who just looks younger than he is! I thought you might be a fourteen-year-old genius," said Kalyn.

"I'm sorry," he said, cautiously.

"Oh, I'm not!" Before he quite realized what was happening, she was teaching him how to kiss. And before he could get away, he realized that he liked it. She tasted sweet too. Preoccupied while the sun set and the stars came out, they didn't notice Ed wandering across the plaza, admiring the Milky Way, cutting close around the corner of the telescope housing, until he almost tripped over them.

Now, Ed smiled at him. "Kay's a nice girl. I approve, in case you were wondering." Ed changed the subject back. "So the captain can't let you back in. His loss will be my gain, I hope. I can offer you a job at the Observatory. Technical apprentice."

"Thank you—very much. . ." Mark stammered.

"But—?"

Mark confessed, "I'm not sure I'd be happy at the Observatory, either, forever."

"I'm not hoping for forever, just more than the three months we had our last sharp apprentice! Normally we get two kinds of app tech: the terminally lazy and the up and coming who up and go somewhere more prestigious. Stay a couple of years. You can save up money

for college. And practice your social skills, too. Sound good to you?" Ed raised a bushy white eyebrow at Mark, winsomely.

Mark nodded. And then he sneezed. "Gesundheit."

Through the window of the Sand Rover, Mark heard a distant noise. "Ed, they're coming. Janet Warren is supposed to be with them."

"What?!" Ed started straightening his clothing and fumbling for a comb.

Mark jumped out of the Sand Rover. Leading the way toward the vehicles in the lot, Mark sneezed again.

Suddenly he felt good. Even with this cold coming on. Even though he knew how much the Outside could hurt, and today he had seen the cozy green goodness of the Inside, unattainable, for him, forever. He felt good anyway. He had a job and a safe place to stay while he learned about the Outside world, how to live there and—he softly gasped, adding it all up for the first time—how to love. Kalyn had been inquiring about the state of his feet for days. Yesterday she had said—offhandedly, but with an interested blue gleam of her

eyes: "When your feet are all healed up, we can hike over to Juniper Canyon. There won't be anybody else there, especially not old guys walking around stargazing!"

Mark made himself stop thinking about the future. He had work to do right now. Janet Warren must be the gray-haired woman in a bush jacket and safari hat, vigorously climbing out of the jeep. It occurred to Mark that she might be receptive to a walking tour around Ecosphere. She was dressed appropriately. And it would only take twenty minutes.

Ed had really liked the chrysalis idea. Maybe Dr. Warren would, too. Mark quickly planned how to say it, tell her that the Ecosphere was packed full of Earth's life, but not just that, knowledge too. Ecosphere held twenty years and fifty lives' worth of discovery about what makes a world work. Mark would evoke the image of a Monarch butterfly in its chrysalis, ready to emerge and unfurl the beauty of its wings and fly a great distance; and here, an emergence as glorious as that, destined to fly the greatest of all distances: to the stars. ■

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● Obviously a man's judgment cannot be better than the information on which he has based it.

Arthur Hays Sulzberger

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# the reference library

By Tom Easton

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**Dark Sky Legion**, William Barton, Bantam, \$4.99, 416 pp. (ISBN: 0-553-29616-7).

**Oracle**, Mike Resnick, Ace, \$4.99, 256 pp. (ISBN: 0-441-58694-5).

**The Alien Heart**, Mike Resnick, Pulphouse (Box 1227, Eugene OR, 97440), \$25 (limited cloth edition), \$4.95 (trade paper), 103 pp. (ISBN: none).

**Raft**, Stephen Baxter, ROC, \$4.99, 303 pp. (ISBN: 0-451-45130-9).

**A Fire upon the Deep**, Vernor Vinge, TOR, \$21.95, 391 pp. (ISBN: 0-312-85152-0).

**Anvil of Stars**, Greg Bear, Warner/Questar, \$19.95, 442 pp. (ISBN: 0-446-51601-5).

**Stopping at Slowyear**, Frederick Pohl, Axolotl (Pulphouse Publishing, Box 1227, Eugene, OR 97440), \$10 (tp), 118 pp. (ISBN: none).

## Books on Disk

It's easy to take the passion for order, the battle against chaos and change, as the driving force of civilization. It is less easy to see, at least for the sort of conservative, neophobic mind that runs governments, that too much order is catastrophic. Neophiles, among whom we must count science fiction writers and readers, have no such problem. Certainly William Barton doesn't, for in **Dark Sky Legion** he has managed to build a marvelous tale with a unique view of future human civilization best capsulized in the line "A passion for order gone mad."

Barton posits a "Red Millennium"—1450-2450 A.D.—of scientific inquiry and technological progress culminating when the mad dictator Cpaht marched Earth's population—all but his own folk—through matter transmitters to record their forms and minds in the hydrogen ice memories of slower-than-light starships and shipped them off to the stars, each city or ethnic group to a different world. This "metastasis" was quickly followed by Cpaht's fall and the rise of the Metastable Order, dedicated to ensuring that the myriads of human

worlds remain within bounds of civilized behavior as defined by the Order's central body, on Earth. Unfortunately, the Order is spreading, by the time of the story it occupies a quarter of the galaxy, and the Einstein limit makes the logistics of control quite staggering.

Meet Maaron Denthurion. As a youth he agrees to become a Televox, an agent of the Order's efforts to control. Once he is educated, the matter transmission technology is used to duplicate him. The original will remain on Earth, kept alive for tens of millennia by the editing capability of the matter transceivers. The duplicate, stored in the black hydrogen ice of a starship, will go to the stars, stopping at worlds to check for adherence to the centrally dictated norms. Occasionally it will be reduplicated. Periodically, each duplicate's memories will be sent back to the original, keeping that Denthurion abreast of affairs in the widespread civilization he helps to govern.

One Denthurion thus lives continuously and forever. The others—many others, eventually—live for a few years at a time, with long gaps of interstellar travel; as a collective, they live as long as the original, but thanks to their multiplicity they have many more years of life-experience. Denthurion is thus a character whose identity is hard for a writer to write about. Barton succeeds admirably well in his task by sprinkling numerous excerpts from the lives of the Televoxes throughout his book, using them to space the events of his plot and to provide glimpses of the nature of the Metastable Order, the stasis it imposes on human culture for half the life of the species, and the horrors it produces in the name of that stasis.

The plot, the story all Barton's intense imagination serves, begins when Denthurion reaches the world of Olam,

where a native species has degenerated to household pets and a pseudo-religious cult is using matter transceivers to beam believers up to God's Starship, where they will become members of the Crew. Now, natives don't get decent treatment anywhere in the Metastable Order, but putting collars and leashes on them smells pretty rancid. And this Starship business smacks of the madness that was common in the Red Millennium and was supposedly stamped out long, long ago. Denthurion must display a talent for poking and prying in order to find the roots of quite a nasty scam and purify the local branch of the Order. He is as nasty and ruthless as the cult leaders, but since he is so in the name of Order and even in defiance of his own sentiments, he's a good guy. Isn't he? *He* thinks he is.

Barton treats him sympathetically enough. But Barton also makes it clear that he himself feels a stasis that lasts so long is no utopia. Denthurion may be a nice enough fellow, but he's still a dictator's thug.

*Could* stasis last so long? The worlds of Barton's Metastable Order tend to be visited by Televoxes quite rarely. They may, in fact, go five thousand years between visits. Granted that the Order can marshal enormous military resources and is not loath to destroy totally an aberrant world that refuses to bow—or even one that does bow, if the Order thinks its aberrancy is too deeply embedded—such long intervals of independence would seem quite enough to develop a technology equal to that of the Order.

I thus have very strong doubts about how feasible Barton's scheme could be. But those doubts are only afterthoughts. While I was reading, Barton successfully convinced me to suspend my disbelief. He has created a Galactic Empire

as convincing as any of those created by the two authors to whom he dedicates his book, Poul Anderson and Frank Herbert.

As deftly told as ever, showing stronger signs than usual of the author's love of Africa, *Oracle* is the second volume in Mike Resnick's trilogy about Penelope, the girl who can see the myriad futures and, because she can also see which of her actions are associated with whatever future she desires, seems to exert almost godlike control over what is to come. Look at her: She moves across the room, stepping *so*, gesturing *thus*, dropping a glass, dancing a dance of fate as she selects the futures in which she rules the universe.

We first met Penelope in *Soothsayer*, when she was a mere tyke using every shred of paranormal power she possessed to escape those agents of the Democracy who had taken her from her parents, those humans and aliens who stole her again, the bounty hunters who hoped to seize or kill her for the Democracy. At the end of that book, she was surrounded by corpses, the Iceman—barkeep; ex-spy master, keeper of secrets—was injured, and she was departing with the alien Mock Turtle for the life of a goddess. As *Oracle* opens, Penelope's supposed mother has come to the Iceman, saying she wants her baby back, she knows where she is, maybe, and would he help her, please? The Iceman promptly spots her as a ruse of the Democracy, sets a price, and sends the Whistler off to the Blue Devils who may or may not be hiding Penelope on their world of Hades. He is to fetch or kill as opportunity permits. But then the Democracy, having second thoughts about the advisability of letting Penelope loose upon the galaxy, decides it would be better just to kill. Enter assass-

sin Jimmy Two Feathers, known as the Injun.

Despite the threat they pose to Penelope, both the Whistler and the Injun proceed smoothly on their paths. Is the Oracle then weaker than she seems? Is she a prisoner of the Blue Devils and therefore welcoming the new arrivals as a means of escape? Are they mere pawns in some larger scheme? I will say no more than this: Penelope doesn't even enter the story, in the flesh, until the last eighth of the book. *Oracle* is a fairly typical middle volume of a trilogy, a bridge between beginning and end. Resnick here takes considerable care to define Penelope's powers as awesome and frightening, to hint that she will leave Hades and wreak havoc on the galaxy and yet, in time, fall. How will she fall? Resnick plants the clue: As she grows able to see farther into the future, Penelope will find the possibilities grown so numerous (as they must!) that scanning them all will consume so much time that she will never be able to act in time to save herself.

Now watch him make a fool out of me by doing something else entirely.

If you would like eight Resnick short stories to go with the novel, you might look for *The Alien Heart*, number 25 in Pulphouse's "Author's Choice Monthly" series. The title reflects Resnick's claim that all his fiction is about the human heart, or "at least the alien heart—which is simply the human heart held up to the mirror that we call imaginative literature, or, more commonly and inaccurately, science fiction." "Beachcomber" concerns a robot travel agent that falls in love with the dreams it peddles. "Me and My Shadow" deals with the return of memory to a memory-wiped and rehabilitated criminal. The mawkish sentiment

of "The Last Dog" probably explains why Resnick was able to sell it sixteen times "to canine markets." "Watching Marcia" is a nasty little tale of sexual obsession with an anti-statistical surprise. "Beibermann's Soul" is about a writer who mislays his soul and finds success. "One Perfect Morning, with Jackals" offers us the infamous Koriba's last day on Earth. "Frankie the Spook" is the ultimate ghost writer. "Balance" considers how unfortunate Asimov's Dr. Susan Calvin might have been to be so identified with robots.

In his first novel, **Raft**, Stephen Baxter offers us a variation on the setting of Larry Niven's *The Integral Trees*. However, where Niven's tale took place in a ring of life-bearing atmosphere surrounding a relatively normal star, Baxter's happens in a cloud, a nebula of tiny (hundred yard diameter) stars which rush through their life cycles in mere years and thus convert the nebula's initial stock of hydrogen into oxygen and other materials essential for life. The nebula itself seems to be about the size of Earth, and visible beyond its edges are others. In this nebula are numerous living things, including flying trees shaped—despite the cover committed by an "artist" who apparently didn't read the book—like wheels.

The difference between Baxter's universe and our own is simple: the force of gravity is a billion times as powerful as it is in our more familiar realm. This presents the nebula's human residents, descended from the crew of a ship that blundered through a hole in space, with unique problems (any too-large building has a tendency to implode) and opportunities (iron can be mined from the surface of a dead star with a surface gravity of just five gees).

The story's hero is Rees, a young

miner with an inquiring mind. When he figures out what the reddening of the nebula's light means, he stows away on a tree (used for transportation) to reach the Raft, a broad disk built of fragments of the original Ship and the star-mine's iron, and tries to do something to save his world. Before long, he is in training as a scientist, learning something of the tides of discontent beneath the Raft society's surface, refusing to join the revolution of the proletariat, being exiled back to the mine and thence to the realm of the cannibal Boneyes, hitching a ride on a "whale," and seeing how, just maybe, his people might escape to a new and hydrogen-rich nebula.

The tale moves right along, and it's short enough that no one need feel enslaved to it. And if that comment seems a mite strange, it's rooted in the thought that if the book were much longer, Baxter's logical lapses might well become so aggravating that a reader would feel chained to the reading (after all, these days books are too expensive to quit part-way through). He seems to think that orbits can be maintained against air resistance with minimal effort, that steam jets can run indefinitely with neither fuel nor water, that at hypersonic speeds through dense air a door can be opened in the side of a spacecraft without totally destroying the ship, that . . .

The enlargement of gravity, the solution to the nebula's death, and many other products of Baxter's imagination are worthy of Niven and deserve respect. Much of the rest may remind you more of L. Ron Hubbard, but Baxter's first novel remains very promising.

Vernor Vinge is a computer scientist and professor at San Diego State University who doesn't pay nearly enough attention to his true calling. That is, we must wait far too long between his nov-

els, which tend to be marvelously ingenious, well peopled, and compulsive page-turners, unlike much else in the "hard SF" area.

His latest—**A Fire upon the Deep**—is no exception. Vinge supposes a far, far future time, long after humanity's first spread from Earth into the galaxy, at least one collapse to savagery, and its reascent. At the time of the story, humanity is but one among a host of sentient species, some humanoid, some not, some young, some senescent, all coexisting in a metacivilization constrained by the very nature of the galaxy.

What is that nature? Here Vinge shows the surpassing quality of his imagination. In the central regions of the galaxy, known as the Unthinking Depths, physical laws are such that thought is impossible to living beings or to artificial constructs. Outside that zone lies the Slowness, where organic beings can manage at least a muddled sort of thought and the Einstein limit to the speed of light is real; this is where Earth lies. Outside the Slowness lies the Beyond, where minds of all sorts whiz like mad and the lightspeed limit is sheer fiction. The boundaries between the zones are not abrupt; thinking efficiency and travel speed increase gradually with distance from the galactic center; the boundaries are thus thresholds, and they are both irregular and subject to variations, or stormlike surges that can thrust border worlds in and out of the Slowness with catastrophic effects.

There is another boundary too, this one on the far side of the Beyond. Cross that, and an intelligence, a world, or a civilization becomes Transcendent, godlike. Perhaps oddly, Transcendent Powers tend to live for no more than about a decade; they burn out fast. And there are hints of further levels to the sentient cosmos, further out and less

comprehensible even than the godlike Powers.

Vinge's tale begins when a group from the largely-human Straumli Realm (in the Beyond) sets up a lab on a ruined world just over the boundary of the Transcend. They are studying an ancient computer archive, unraveling and testing the long-stored programs. Unfortunately, one of those programs is an inimical intelligence that can seize control of other intelligence, both organic and electronic. Fortunately, the researchers realize what they are doing just—or almost—in time. They load their children into a freighter with the one item from the archive that just might someday prove a defense against the monster. Unfortunately, the monster reacts in time to destroy the freighter's guardian frigate. The freighter flees, diving desperately toward the Slowness, where even monsters cannot function. Its crew consists of mother, father, eight-year-old Jefri, and fourteen-year-old Johanna. The rest of the kids are in cold-sleep.

Step now to the world of Relay, where an ancient consortium has grown wealthy and powerful by serving the communication needs of part of the galaxy. There is only one human here, the female librarian Ravna, and when word comes that Straumli Realm has fallen to some Transcendent evil—the Blight—she becomes of immense interest to many, including those who wish to blame humanity for the problem and destroy it.

Go now to a world near the Slowness as that desperate freighter lands on a hilltop, its small crew emerges, and the medieval locals attack with murderous effectiveness. The parents are dead. Jefri and Johanna are in the hands of a group—the Flenserists—that believe in the perfection of society by murderous

means and are ruled by Lord Steel (surely named after that human who took the same name to express his ruthless determination—Stalin). Johanna is rescued by a different group, the more congenial Woodcarvers. Later Jefri will use his access to the ship and its communication gear to give the Flenserists access to more modern technology such as cannon. Johanna has with her a child's portable computer stuffed with teaching programs and encyclopedic databases and will soon give the Woodcarvers access to similar gadgets. War very quickly seems inevitable.

The aliens—the Tines—themselves are a marvelous conception, and their society is a fascinating exercise in implication. Each individual is a small pack of doglike animals. They have no hands, but their multiple sets of prehensile lips serve the same purpose. They coordinate not by telepathy—Vinge respects reality too much for that—nor by radio, but by sound, each member of a pack keeping up a running, chattering report on its mental activity, apparently using different frequencies for thought-sound than for speech-sound. Different packs therefore cannot mingle without losing their “minds” (hence sex is a distinctly mindless activity). Nor can a pack's members move very far from each other. And a pack's personality depends very much upon its specific makeup, the manipulation of which is the key to the Flenserists' nastiness.

At Relay, Ravna is part of a team preparing to pursue the freighter to the world of Tines and gain whatever defense it may carry. Her colleagues are two bushlike Greater Skroderiders and a man, Pham Nuwen, constructed from parts by an elder Power. The Blight attacks Relay. The Power fills Pham with godshatter as it dies. Ravna and her fellows escape in a ship that was not quite

ready. The Blight's armada pursues, as do the forces of those who wish to destroy all trouble-stirring humans and the surviving defenders of Ravna's home system.

Meanwhile, on the Tines' world Jefri is being subverted by Lord Steel, who craves the secrets of the space-travelers, plots to capture them, and dreams of conquering the stars themselves. Johanna is helping the Woodcarvers. There is a possibility that the coming war will destroy everything, including the defense against the Blight.

Meanwhile, aboard Ravna's ship. . . . You get the idea. Vinge jumps from one scene of mounting suspense to another. The reader grows breathless, carried away in a way that only the very best science fiction can manage.

Do you think that everything has to turn out OK in the end? You're right, but only in a sense. The greatest problems are indeed resolved. But there is a very high price. There is also the potential for a sequel or two.

Back in 1988, I gave Greg Bear's *The Forge of God* high praise. His vision of the destruction of Earth by the robotic minions of a culture that could brook no potential threat among the stars was a grand-scale tear-jerker marred mainly—and understandably, to be sure—by an excess of terminal vengefulness. The vengeance was to be carried out by Earth's few survivors, those rescued by the Benefactors, aliens who did not believe in destroying other species although they did have a Law that destroyers must in turn be destroyed by their victims (even though a pest control agency might seem more appropriate). The shape of humanity's future history was clear. So too were the main features of a sequel.

That sequel, *Anvil of Stars*, is now

available. It is, alas, more deeply flawed than *Forge*. As I said in the earlier review, Bear should have stopped one chapter before the end of that book.

The situation is simple. A crew of young humans is aboard the Ship of the Law, *Dawn Treader*. Their mission is to search out and destroy the nasties. They are innocent, Lost Boys and Wendys both, led by an elected Pan, playing at politics and love and war. And they find their quarry. The resulting disaster—for both them and that quarry—grows them up in a hurry. The process has some grand satisfactions for the hard-SF fan as Bear describes the Ship of the Law and its underlying technologies, the boobytrap that is the star Wormwood and its strange planets, the alien Brothers (each one of whom is an assemblage of individuals reminiscent of Vinge's Tines) in their own Ship of Law, and finally the glorious civilization that belongs to the destroyers of Earth and other worlds. Together the humans and Brothers are able to see in the destroyers' superscience clues that enable them to improve vastly on the Benefactors' technology. They triumph easily, and in due time, seeing themselves as dogs of war that can never return home, the humans go off to find a world of their own and settle down.

One might consider the instant superscience that wins the day a flaw. On the other hand, it is a ploy with an honored tradition behind it, and Bear has established a pattern of nods to tradition with his references to C. S. Lewis, James Barrie, and others. A more serious flaw seems to me to lie in the logic that is at the heart of the tale: Bear takes great pains to tell us that the destroyers destroy to create a vacant zone 'surrounding their home, from which no threat may arise. Yet they know that missions of vengeance may come their

way. They therefore hide behind layers of deception and deadfalls, even making their entire solar system seem vacant.

The major flaw I see is this: If they can so control the image of a solar system in order to avoid attention, they could hide in the midst of a sea of enemies. Why then do they insist on *attracting* attention with their missions of destruction? If you wish to dig a hole, jump in, and pull the hole in after you, *you don't put up signs saying, 'Looky! Looky! There's a hole here!'*

It is not enough to say, as Bear might, that evil always contains the seeds of its own defeat.

Frederik Pohl's latest is a novella of considerable interest, **Stopping at Slowyear**. The future he posits is one of relativistic tramps such as the obsolete starship *Nordvik*. It left Earth centuries before with cargo its crew hoped to sell to the colonies Out There. At each stop they sell what they can and buy what they think might sell at their next stop. Alas, while the ship and its crew take mere years between the stars, the colonies pass centuries. The *Nordvik's* wares have a tendency to be sadly obsolete. Its crewfolk are depressed. The ship is deteriorating. The aged Captain has been supplanted by a pig of a deputy. And Mercy MacDonald—one of the few of the original crew who has not already jumped ship—has about had it.

But hope springs eternal. Here is a new system, a habitable world, a colony. There are peculiarities, including a year twenty times what humans evolved to fit, but the locals are as delighted to have visitors as the visitors are to visit. Mercy, resolved to leave the ship and settle here, permits an affair with a local philanderer. Other crew members decide to stay as well.

And alas again, there are signs of worm in the apple: a high infant mortality rate, a long-stable population, a captain stripping in the marketplace. The crew learns, far too late, that they may never leave. The reason why I will not reveal, except to say that it is firmly rooted in something known on Earth and so far quite resistant to analysis or cure. Pohl has devised a very believable disaster.

### BOOKS ON DISK

I don't often announce in this column forthcoming books or projects that may or may not come to pass. But there's always room for an exception. Last New Year's Day brought a call from

SFWA member Wolfram Friedrich (Federico) Schaffler-Gonzalez, a Mexican who can be reached at P. O. Box 3718, Laredo, TX 78044 with questions or encouragement. He told me that he and other Mexican science fiction writers want to start a Spanish-language on-disk SF magazine along the lines of one they ran into at a con in Brazil. Did I know of any software that would help them do the job? Once I had told him of Ted Husted's IRIS and PRISM programs (used, for instance, to produce *ShareDebate International*), he promised to send a copy of an anthology of Mexican SF he had recently edited.

I can't read Spanish, but I'll still let you know when the book gets here. ■

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## IN TIMES TO COME

● Nicholas Jainschigg's October cover illustrates another colorful and thought-provoking adventure tale by Campbell Award winner Julia Ecklar: "Ice Nights." This one involves a peculiar sort of contraband—even more peculiar than ecological engineer Rahel first realizes. . . .

Our fiction line-up will also include a little something for Columbus Day—written interestingly enough, by one of *Australia's* rising talents. And of course, part two of Kevin J. Anderson and Doug Beason's *Assemblers of Infinity*.

Martyn J. Fogg provides the fact article, "A Planet Dweller's Dreams," about a kind of planet that may be the most important in human expansion through the Galaxy; the kind that's *almost* habitable. And if space permits, we'll try to squeeze in an "educational" special feature or two. . . .

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# brass tacks

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Dear Dr. Schmidt:

Your mid-December editorial, "The Perils Of Victory," put words to the feelings that I have had for some time now. The ultra-nationalistic, "kick butt" type of patriotism exhibited during the Gulf War is nothing to be proud of and can even be dangerous. Feelings like this only foster an "us" versus "them" attitude that inhibits closer world relations. It is time for this world to realize that we are, after all, the human race and not isolated pockets of peoples spread across the planet. We have much more in common than we have different, and together we can make this world a much better place to live.

Other than the section on pep rallies being dress rehearsals for stirring up wartime emotions (which I felt was reaching a bit), your editorial was right on the money. No doubt you will receive some criticism for your politically incorrect views, but I applaud your forthright assessment of the situation.

PAUL S. ROSIK

1212 Level Green Boulevard  
Virginia Beach, VA 23464

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Dear Stan,

What a great double issue (January 1992)! Not only was there a story ("Secret Names") by the redoubtable Harry Turtledove extolling the Queen of Sciences, taxonomy (now sadly something of a Cinderella to most biologists); but this was followed by another on the virtues of marsupials, my special interest. It is the latter ("An Empty Wheelhouse") I comment on.

Sean McMullen is obviously well-informed about the range and diversity of pouched mammals, and his—or rather his character Neil's—comparison of the wateroo with the South American yapok (or water opossum) is apt indeed. That

the wateroo might be an evolutionary descendant of the yapok seems probable to me for several reasons, most especially because—as the author implies—an animal like the yapok, with its highly responsive “fingers,” might well be expected to develop electrosensitivity.

However, other marsupial biologists may disagree, for McMullen commits the common error of assuming that what Australians call “possums” are closely related to the American *opossums*, which is by no means the case. Opossums are carnivorous beasts, with many sharp, pointed teeth; Australian “possums,” on the other hand, are herbivores (close relatives of kangaroos, wombats, and the koala) with rodentlike enlarged front teeth and mostly grinding molars. The Australian misnomer confuses two very different groups that seem to have been separated for a long time, both evolutionarily and, so far as we knew before “An Empty Wheelhouse,” geographically. Needless to say, it would be most interesting to know what kind of teeth wateroos have, and I trust McMullen will tell us in a hoped-for sequel.

In fact, I find the prospect of wateroo/opossum relationship most exciting for a personal reason: my laboratory group has recently shown, using comparisons of marsupial DNAs, that the “obvious” division of marsupials into evolutionary groups defined on geography (Australian vs. American) is incorrect. There is a small Chilean marsupial whose nearest relatives are the group that includes Australian “possums,” the most anatomically advanced of marsupials. Clearly, when the southern continents were united, there was abundant opportunity for marsupials to travel widely; it seems likely to us that the Chilean species is a back-migrant from

Australia. There is thus no reason that other “American” marsupials, such as a close relative of the yapok, might not turn up in Australia.

Two more reasons why wateroos may be true opossums occur to me. First, carnivores tend, on the whole, to be more intelligent than herbivores: if exceptional intelligence were ever to evolve among marsupials, a species with such a “headstart” is the best candidate.

Second, opossums—but not Australian “possums”—have naturally split brains; they lack a corpus callosum, the connection that facilitates easy transfer of information between the two cerebral hemispheres in mammals like ourselves. This means that such marsupials, unlike placentals, who it seems are capable of thinking no more than six impossible thoughts before breakfast, are able to hold an infinite number of contradictory ideas. What an advantage in our modern, irrational age! No wonder we placental mammals are “out to get” these intellectually advantaged wateroos! The herbivorous “possums,” on the other hand, have structures analogous to the corpus callosum that would prevent them from realizing fully the intellectual benefit enjoyed by opossums.

Clearly, McMullen must enlighten us on the affinity of wateroos. It now remains the one great mystery of marsupial phylogeny, and all he really need do to test my prediction that they are carnivores is look in their mouths.

While I anxiously await the answer, I’ll ask you, Stan, to pass on the enclosed reprint and keep up the flow of wonderful stories with biological content.

JOHN KIRSCH

Madison, WI

*The author replies. . . .*

Originally the story was about 2,000 words longer, but I cut out a lot of my detailed research because it seemed to disturb the flow of the story and would probably only be of interest to professional zoologists! Yeah, well. . . .

The point about the dentation is quite a good one, and I gave it some thought before writing the story. The platypus occupies a similar niche to my proposed wateroo in the Australian environment, and it—like the yapok—is a carnivore, at least in the sense that they hunt a parallel range of prey. Could a vegetarian marsupial make the transition to this niche? I took this problem to a tame zoologist, and he pointed out that there are precedents for animals modifying their eating habits over a fairly short period in the evolutionary time scale. The giant panda appears to be recently descended from a carnivore, and its dentation—so I am assured—is more that of a carnivore than the herbivore that it now is. My idea was that the possum-related wateroo went in the opposite direction: herbivore to carnivore. Thus if you looked at the wateroo's teeth, they would probably look like those of a herbivore, with some modifications for grinding up its prey in the way that the platypus does with the bony plates of its bill.

Thus I appear to have identified the same problem as Professor Kirsch but coped with it rather differently—my speciality is computers, after all. As I mentioned in my earlier letter, I was deliberately a bit lax with my possum/opossum terminology for the sake of sparing your readers further complexity in an already complex story. With hindsight, that now looks like a bad move, and I'll try to make amends. The story has already been accepted for reprint in Australia in a book due to be published in a couple of years, so I shall insert some

lines of dialogue to make the possum/opossum distinction.

If the wateroo turned from herbivore to carnivore to exploit a small unoccupied niche, then it might well be just as vulnerable to environmental disruption as the giant panda. That would (1) reduce the population to the level required by the plot in my story and (2) make the wateroo a carnivore (or at least an omnivore) among herbivores. Point 2 is particularly important, because I wanted to have some good reason for the wateroos to develop high intelligence and as Professor Kirsch (and an article whose reference I am mortified to say that I have mislaid—it may have been in *Nature*) points out, carnivores tend to have an edge over herbivores in intelligence. Thus a creature that is already fairly bright develops the ability to project and detect electromagnetic fields. This also gives it a communications tool as rare as human vocal chords, and if the theory that human language and intelligence built each other up in a feedback effect is true, then the same might have happened with the wateroo.

Why should wateroos be able to project fields instead of just being able to detect them from the muscular impulses of their prey, as in the platypus? One reason might be that the fields generated from their fingers would tickle stationary (and thus 'invisible' prey) into moving, and thus giving themselves away by the bursts of electric noise from their muscles.

Opossum brain physiology: that's really wonderful about the lack of a split brain: no I didn't know about it, and yes I would have used it if I'd known. It implies something very interesting about the systems design (for lack of a better term) of their cognitive pro-

cesses, but I would rather say no more until I think all the ramifications through for myself.

So, to answer Professor Kirsch: yes he is right, they are carnivores, but if he looks in the mouths of my original version of them, then he will probably be a bit surprised by the dentation. On the other hand, the idea of having an animal with a split brain but no corpus callosum holds so much attraction that I am tempted to make wateros bonafide opossums and carnivores, which were isolated in Australia by the Gondwanaland fragmentation. Just as well that I did, in fact, cut out all that background material in "An Empty Wheelhouse."

SEAN MCMULLEN

Dear Dr. Schmidt:

Alternate universe stories are an established part of science fiction, but they should be identified as such. In the letter column of *Radio Free Thulcandra*, a Christian-oriented fanzine I edit and publish, people have been compiling evidence that *Robin Hood: Prince of Thieves* is set in an alternate universe. It ranges from the implied presence of numerous accurate clocks in the Middle Ages to the fact that the characters are not humans but humanoids for whom caesarean childbirth performed without anesthetics or sterile conditions is only a minor inconvenience from which the mother recovers fully in a day or so.

Mary Caraker's "Taboos" in the January issue is also an unacknowledged alternate universe story. It is set in a universe with a religion, the New Fellowship, that is described as "an alliance of the most conservative elements from across all Earth religions." In our universe the theologically conservative members of any religion are the ones most likely to stick to their own

theology and avoid syncretic union with other religions. Theological liberals are the ones most likely to seek interreligious unity because they can agree that none of them really believe much of anything. (*Radio Free Thulcandra* has a readership that ranges from Fundamentalists through Catholic and Eastern Orthodox Christians, to liberal Protestants, along with some non-Christians, but I exclude theological debate.)

The New Fellowship teaches monogamy, but in our universe Islam, which is widely regarded as a conservative religion, permits a man to have up to four wives. The Mormon religion, also regarded as conservative, had plural marriage, but says it received a new revelation in 1890 to suspend it until the millennium, when it will be reinstated. Many of the "most conservative" Mormons choose not to wait and illegally practice polygamy today. The Mormon religion is also the only one I know of that has a doctrine of continuing revelation. Traditional Christianity and Islam both firmly reject that idea.

Religion is a basic element of human experience, and authors who write about it should get the facts straight, just as they should get the facts straight about chemistry and physics, regardless of their own beliefs. One need not be a Hindu to know that there would be something wrong with a story in which a character described as a devout Hindu is shown ordering and enjoying a roast beef dinner.

This objection aside, I agree with the point of the story that "taboos" should not be cast aside lightly. One must know the real reason for a custom before changing it. Assumptions based on current ideology are not enough.

MARTY HELGESEN

11 Lawrence Avenue  
Malverne, NY 11565-1406

*The author replies. . . .*

I can't agree that "Taboos" is an alternate universe story any more than are others of my space teacher stories set in the 24th century. I am quite aware of the "facts" of the religions from which the New Fellowship has splintered, and whether or not in 400 years they would be able to reach an accommodation on such issues as monogamy and revelation might, I think, be dictated by their circumstances and need. In "Taboos" I don't go into the reasons for their leaving Earth, but any group, including the New Fellowship, would presumably not have chosen to emigrate without compelling ones. Conditions on their new world, as I indicate in the story, would further shape the theocracy that emerges.

The nature of change is a point of the story.

MARY CARAKER

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This letter is addressed to anyone who reads, writes, edits or is otherwise associated with *Analog*, now, in the past, or future:

*Help!* I have been a fan of this magazine for a long time now, and the more I read it, the better I like it. Especially the humanism of the stories and articles that are published herein.

I consider Miles Vorkosigan to be one of my heroes: he has *chutzpah* and represents all the people who have succeeded because of their "handicaps." I also firmly believe in the inherent rightness of using technology to make life better for people, and I pride myself on my ability to look behind the apparent differences of others for the commonality that lies inside, and in the same breath I can say, "*Vive la difference!*"

That is, as long as I am reading this

magazine! When I get out into the "real" world, I find myself shying away from risks, resentful of new devices I don't understand, and prejudiced against people who don't think the way I do, or who lack my "superior" heritage. Does that make me a hypocrite? Or just normal? How do I live up to the ideals that keep me reading this magazine? How do I make my beliefs into action?

Why don't I ask my friends for help? Well, it seems that I haven't found anyone else around here who is willing to admit that they think about these things too, but I know that other *Analog* readers do, and may have some solutions. Anyone who has an honest suggestion is welcome to write to me. If Drs. Schmidt or Stine would like to create editorials based on this letter, I would be highly honored. All I want is some help, some suggestion of how others have been able to reconcile the differences between *is* and *ought*.

MICHAEL D. ENQUIST

1500A E College Way #484  
Mount Vernon, WA 98273

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Dear Stan and Tom,

I'm usually very reluctant to respond to reviews, especially when the reviewer has been fair and even complimentary about past works he's reviewed. But Tom's review of "Heads" can't pass without some comment.

Indeed, the book is a novella, and one of the plot points—the identity of a single frozen head—is strongly telegraphed. That could be criticized, and perhaps justly, although I never intended it to be the sole reason for the story's creation. "Heads," whatever its flaws, major work or minor, is neither simple nor simplistic.

It is, however, deeply satirical—not funny, but satirical. But Tom says,

"... its essential nature as a Cheap Shot means that we have to call it a minor work."

"Cheap shot," according to the American Heritage Dictionary, means "An unjust action or statement directed esp. at a vulnerable target, as a public figure."

If the story is truly a Cheap Shot, then it is not just minor, it is reprehensible, since it is unjust. In what way are my satirical points unjust, Tom?

GREG BEAR

Dear Dr. Schmidt,

Thank you for publishing Mr. Potts's reply to me concerning free markets in your January issue; the subject is certainly a topic for debate. To be very brief, while recognizing that free markets do a better job of creating gross wealth than state control can with our existing economic tools, I don't think that free markets *alone* do a morally acceptable job of *distributing* jobs and wealth. Also, there is what I call the snake oil salesman effect. That's when the snake oil salesman skips town with his profits before people find out that the stuff's no damn good and has lousy side effects. This kind of time lag defeats the checks and balances of a laissez-faire market and builds up an enormous reservoir of social costs; unfettered human nature

can get a little ugly.

I think the most effective economies provide a structure of rules for the game (tax rates, credits, interest rates, non-compliance penalties, etc.) which reward socially responsible behavior, and that this kind of rule management can become increasingly effective as our computational capabilities to model economic chaos increase. For instance, I think a good case can be made that, using computational tools, the Federal Reserve is already doing a pretty good job of maintaining price stability through manipulating various economic rules. One must take care, of course, to set things up so that the rewards go to the desired behavior without too much expensive oversight.

We have, as Hans Moravec points out in the same January issue, an excellent chance of achieving a robot slave labor economy within a few generations, if that's what we want. Among the challenges before us are: (1) Where do we really want to go? (2) Does everyone have to go the same way? and (3) How can we handle the transitions as humanely as possible? If you add to this the possibility of making some genuine improvements to human nature, the arguments for laissez-faire market economics begin to seem a bit dated and naive.

GERALD D. NORDLEY ■

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Martin Vanbee

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a calendar of  
**analog**  
upcoming events

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### 14-16 August

**BUBONICON 24** (Albuquerque area SF conference) at Ramada Inn East, Albuquerque, N. Mex. Guest of Honor—Thorarinn Gunnarsson; Artist Guest of Honor—Dell Harris; TM—Walter Jon Williams. Registration—\$23 at the door. Info: NMSF Conference, Box 37257, Albuquerque NM 87176. (505) 266-8905 [10am to 10:30pm].

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### 3-7 September

**MAGICON** (50th World Science Fiction Convention) at Orange County Civic & Convention Center, Orlando, Fla. Guest of Honor—Jack Vance; Artist Guest of Honor—Vincent Di Fate; Fan Guest of Honor—Walter A. Willis. Registration—\$110 adult/\$55 child until 15 July 1992; \$135 adult/\$75 child at the door. Supporting—\$25. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Join now and get to nominate and vote for the Hugo Awards and the John W. Campbell Award for Best New Writer. Info: MagiCon, Box 621992, Orlando FL 32862-1992. (407) 859-8421. UK agent Peter Weston, 14 St. Bernard's Road, Sutton Coldfield B72 1LE, UK.

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### 10-13 September

**COPPERCON 12** (Phoenix area SF conference) at Phoenix, Ariz. Guests of Honor—Roger Zelazny and Alan Dean Foster. Registration—\$25 until 26 August, \$30 at the door. Info: Coppercon 10, 2040 East Cypress, Phoenix AZ 85006. (602) 220-9785.

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### 2-4 October

**ROVACON 17** (Tidewater multi-media SF conference) at Arbogate Inn and Salem Civic Center, Salem, Va. Guest of Honor—Marion Zimmer Bradley; Art Guest of Honor—Mary Hanson Roberts; Media Guest of Honor—George Takei; TM—Deanna Lund. Registration—\$15 until 15 September, \$20 at the door. Info: RoVaCon, Box 117, Salem VA 24153. (703) 389-9400.

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### 2-4 October

**CONTEXT 5** (Central Ohio SF conference) at Hilton Inn North, Columbus, Ohio. Guest of Honor—George Alec Effinger; Editor Guest of Honor—Martin H. Greenberg; Special Guest—Joan Slonczewski. Registration—\$30 until 15 September, \$35 at the door. Info: Context 5, Box 2954, Columbus OH 43216. (614) 889-0436.

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### 2-4 October

**CON-CHORD 8** (Southern California filk convention) at Holiday Inn-LAX, Los Angeles, Calif. Guest of Honor—Tom Smith; TM—Joe Bethancourt. Includes kazooos. Registration—\$30 until 8 September, higher thereafter. \$10 supporting. Info: Con-Chord 8, % Rick Weiss, 13261 Donegal Dr., Garden Grove CA 92644-2304. (714) 530-3546 [before 10pm PT].

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### 29 October-1 November

**WORLD FANTASY CONVENTION** at Callaway Gardens, Pine Mountain, Ga. Guests: Anne McCaffrey, Michael Bishop, John Farris, Martin H. Greenberg. Limited membership. Registration—\$100 in advance; NO at-door memberships. Info: World Fantasy Convention 92, Box 148, Clarkston GA 30021. (include SASE)

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You can send me e-mail about your convention—A.LEWIS20 on the GENie<sup>™</sup> network.

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—Anthony Lewis

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*Items for the Calendar should be sent to the Editorial Offices six months in advance of the event.*

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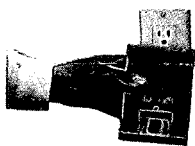
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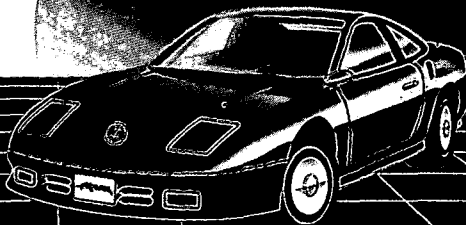
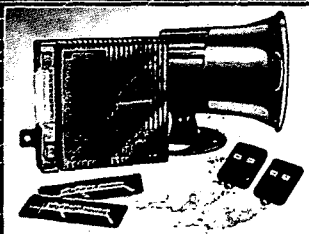
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